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ON
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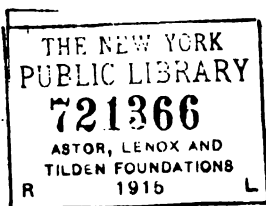
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PLUMBING AND DRAINAGE
GAS AND GAS FITTING
ELECTRIC-LIGHT WIRING AND BELL WORK
WITH PRACTICAL QUESTIONS AND EXAMPLES

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PLUMBING AND DRAINAGE.

653. The duty of a **plumber** is to provide dwellings and other buildings with systems of piping, the several objects of which are:

First.—To supply and distribute water to convenient points.

Second.—To receive and conduct away all dirty and refuse water.

Third.—To conduct away and dispose of all filth, excreta, and other sewage matter, and to remove all noxious odors arising therefrom.

He also provides apparatus for heating water, and for pumping, storing, and measuring cold water.

He provides lavatories and baths, laundry tubs and sinks, water-closets and urinals, cesspools, drains, etc.

The comfort and healthfulness of dwellings, especially in towns and cities, depend in a great measure upon the adequacy and thoroughness of the plumbing. And as the health of the inmates is seriously affected by defective drainage, it is necessary that the work of the plumber shall be thoroughly and conscientiously performed. The general public are profoundly ignorant of the importance of thorough drainage, and in many cases the plumber must protect people against the evil consequences of their own ignorance. In many communities laws have been made which greatly aid him in constructing drainage systems as they should be.

To do his work properly it is necessary that he should possess a complete knowledge of the nature of the materials which may be used for his purposes. He should also become familiar with the mode of performing the necessary operations upon them, both the shop work and the outside work; and he should acquire a clear comprehension of what

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is necessary to constitute an efficient and satisfactory system of water supply, a safe and reliable system of drainage, and a complete and convenient outfit of fixtures and domestic apparatus.

MATERIALS.

654. The nature and variety of the materials which are available for plumbers' use will first be considered.

SHEET METALS.

655. **Sheet lead** is very malleable, and can be worked into almost any shape. Its tenacity is small, and it is apt to tear if stretched very much. It becomes hard and brittle if subjected to much bending or beating.

It is manufactured of any thickness, weighing from $2\frac{1}{2}$ to 10 pounds or more, per square foot.

656. The following table gives, approximately, the thickness of sheet lead for given weights per square foot.

TABLE 24.

Weight per Sq. Ft. in Pounds.	Thickness in Inches.
8	$\frac{2}{15}$
$7\frac{1}{2}$	$\frac{1}{8}$
6	$\frac{1}{10}$
$5\frac{1}{2}$	$\frac{1}{8}$
4	$\frac{1}{15}$
3	$\frac{1}{20}$

Thinner sheets are known as "**tea lead**" or "**lead foil**." Sheet lead never runs exact as to weight, and that grade which measures about $\frac{1}{8}$ inch thick is generally called 7-pound.

657. **Sheet copper** is supplied in two forms, *soft*, or annealed, and *cold rolled*, or mirror finished. Both varieties are tinned on one side, or are left in natural condition as

ordered. It is designated by its *weight in ounces per square foot*. Sheet copper in common use ranges from 10 to 20 ounces, and the largest sheets usually kept in stock of 10-ounce copper are 48×96 inches. The heavier sheets are made 60×96 inches.

Copper becomes hard and tenacious when *worked* or hammered.

The weights and thicknesses of sheet copper are as follows:

Weight in ounces per square foot.....	10	12	14	16	18	20
Thickness in inches.....	.013	.016	.019	.022	.025	.029

658. Sheet zinc is designated by its weight in ounces per square foot. It is furnished in casks or rolls as ordered. The weights and thicknesses are as follows:

Weight in ounces per square foot.....	10	12	14	16	18	20
Thickness in inches.....	.0311	.0457	.0534	.0611	.0686	.0761

Zinc is a bluish-white metal, and is highly crystalline. It is hard and brittle at the ordinary temperature and also at 400° F. But at intermediate temperatures, between 212° F. and 302° F., it is malleable and ductile, and can then be rolled into thin sheets.

NOTE.—The initial letter F is an abbreviation of the word Fahrenheit. Thus, 400° F. means a temperature of 400° on the Fahrenheit thermometer, the one ordinarily used in this country and Great Britain. Unless otherwise stated, all temperatures will be Fahrenheit temperatures, whether indicated or not.

659. Sheet iron is furnished in several varieties, viz., *cold rolled* and hard, or *annealed* and soft. These may be had in the natural state, called **black**, or they may be had coated with metallic zinc and called **galvanized**. Sheets range in size from 24×72 inches for the thin sheets, to 30×84 inches for the heavier ones. Sheet iron is designated by its thickness as measured by a wire gauge. There are

many varieties of gauges used for this purpose which differ greatly in their measurements. The "Birmingham" wire gauge is extensively used by sheet-iron makers. This gauge is usually indicated by the initials B. W. G.

Black sheet iron will endure but very little bending, and galvanized iron will endure still less, because the galvanizing impairs the ductility of the metal. If bent cold the zinc coating will peel off in scales at the bend.

660. Table 25 gives the B. W. G. number, the actual thickness in inches, and the weight in pounds per square foot.

RIVETS.

661. Rivets for plumbers' use are made chiefly of wrought iron and copper. Iron rivets without coating are called **black**, and when coated with tin are known as **tinned rivets**.

The most common form of rivet used in the trade is the common **flat-head** rivet, shown at (b), Fig. 146. This form is used on all classes of thin sheet-iron work.

The **button-head**, or **cup**, rivet (a) in the same figure, is used for joining sheets of greater thickness, particularly if

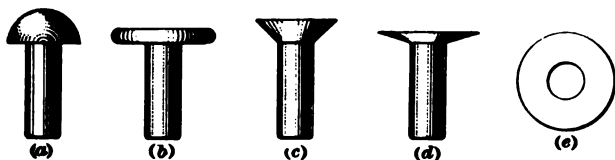


FIG. 146.

they are subjected to internal pressure, or where the riveted seam must be water-tight, such as in an ordinary kitchen boiler.

The **countersunk-head** rivet (c) is used only in joining thick sheets or plates, or other work where the rivet head is desired to be finished flush with the material riveted.

The **brazier's** rivet (d) is made of copper, and is used chiefly on sheet-brass or sheet-copper work.

The **burr**, or **washer**, (e) is generally used with the cop-

TABLE 25.

Number of Gauge.	Thickness in Inches.	Black Iron. Weight in Pounds per Sq. Ft.	Galvanized Iron. Weight in Pounds per Sq. Ft.
1	.300	12.0375	.....
2	.284	11.3955	.....
3	.259	10.3924	.....
4	.238	9.5497	.....
5	.220	8.8275	.....
6	.203	8.1454	.....
7	.180	7.2225	.....
8	.165	6.6206	.....
9	.148	5.9385	.....
10	.134	5.3767	.....
11	.120	4.8150	.....
12	.109	4.3736	.....
13	.095	3.8119	.....
14	.083	3.3304	.....
15	.072	2.8890	.....
16	.065	2.6081	3.00
17	.058	2.3272	2.69
18	.049	1.9661	2.31
19	.042	1.6852	2.07
20	.035	1.4044	1.75
21	.032	1.2840	1.50
22	.028	1.1235	1.32
23	.025	1.0031	1.19
24	.022	0.8827	1.06
25	.020	0.8025	1.00
26	.018	0.7222	0.96
27	.016	0.6420	0.88
28	.014	0.5617	0.75
29	.013	0.5216	0.69
30	.012	0.4815	0.60

per rivet in such places, for example, as on a copper kitchen boiler.

The object of using the burr is to distribute the punching effect of the rivet over a large surface, and thus avoid cracking the sheet or causing it to bulge between the rivets.

Small rivets are put up in packages containing 1,000 rivets. Their size is designated by the weight in ounces or pounds per package of one thousand rivets.

PIPES.

662. Pipes for the use of plumbers are made of many materials, including lead, lead with tin lining, block tin, brass, copper, wrought iron, wrought iron with lead lining, cast iron, fireclay, terra-cotta, and wood.

663. The sizes and weights of lead pipe, tin-lined lead pipe, and pure block-tin pipe, are given in the following tables:

TABLE 26.

WEIGHT PER FOOT OF LEAD PIPE AND TIN-LINED LEAD PIPE.

Inside Diam- eter.	<i>A A A</i> Brooklyn		<i>A A</i> Extra Strong.		<i>A</i> Strong.		<i>B</i> Medi- um.		<i>C</i> Light.		<i>D</i> Extra Light.		<i>E</i> Foun- tain.	
in.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.	lb.	oz.
$\frac{3}{8}$	1	12	1	8	1	4	1	0	0	12	0	10	0	7
$\frac{7}{8}$	.....		.....		.....		1	0	0	13	.....		.....	
$\frac{1}{2}$	3	0	2	0	1	12	1	4	1	0	0	12	0	9
$\frac{5}{8}$	3	8	2	12	2	8	2	0	1	8	1	0	0	12
$\frac{3}{4}$	4	12	3	8	3	0	2	4	1	12	1	4	1	0
1	6	0	4	12	4	0	3	4	2	8	2	0	1	8
$1\frac{1}{4}$	6	12	5	12	4	12	3	12	3	0	2	8	2	0
$1\frac{1}{2}$	8	8	7	8	6	8	5	0	4	4	3	8	3	0
$1\frac{3}{4}$	10	0	8	8	7	0	6	0	5	0	4	0	0	0
2	11	12	9	0	8	0	7	0	6	0	4	12	.....	

664. Lead pipes of any size differing from the above weights are made to order.

TABLE 27.**LEAD TUBING.**

$\frac{1}{8}$ in. $\frac{3}{4}$ oz. per ft.	$\frac{5}{8}$ in. $2\frac{1}{4}$ oz. per ft.
$\frac{1}{4}$ in. $1\frac{1}{4}$ oz. per ft.	$\frac{1}{2}$ in. 5, 6, 8, 13 oz. per ft.

TABLE 28.**LEAD WASTE PIPE.**

$1\frac{1}{2}$ in. 2 lb. per ft.	4 in. 5, 6, and 8 lb. per ft.
2 in. 3 and 4 lb. per ft.	$4\frac{1}{2}$ in. 8 and 10 lb. per ft.
$2\frac{1}{2}$ in. 4 and 6 lb. per ft.	5 in. 8, 10, and 12 lb. per ft.
3 in. $4\frac{1}{2}$ and 5 lb. per ft.	6 in. 12 lb. and up per ft.

TABLE 29.**PURE BLOCK-TIN PIPE.**

$\frac{1}{8}$ in. <i>A A A</i> .. 5 oz. per ft.	$\frac{5}{8}$ in. <i>A A</i> 9 oz. per ft.
$\frac{1}{4}$ in. <i>A A</i> $3\frac{1}{2}$ oz. per ft.	$\frac{3}{4}$ in. <i>A A A</i> ... 13 oz. per ft.
$\frac{1}{2}$ in. 8 oz. per ft.	$\frac{7}{8}$ in. <i>A A</i> 11 oz. per ft.
$\frac{5}{8}$ in. <i>A A A</i> .. $6\frac{1}{2}$ oz. per ft.	1 in. <i>A A A</i> ... 17 oz. per ft.
$\frac{3}{4}$ in. <i>A A</i> 4 oz. per ft.	1 in. <i>A A</i> 14 oz. per ft.
$\frac{7}{8}$ in. <i>A A A</i> .. 7 oz. per ft.	$1\frac{1}{8}$ in. <i>A A A</i> ... 26 oz. per ft.
$\frac{1}{2}$ in. <i>A A</i> 4 oz. per ft.	$1\frac{1}{4}$ in. <i>A A</i> 18 oz. per ft.
$\frac{1}{2}$ in. <i>A A A</i> .. 7 oz. per ft.	$1\frac{1}{2}$ in. <i>A A A</i> ... 36 oz. per ft.
$\frac{1}{2}$ in. <i>A A A</i> .. 10 oz. per ft.	$1\frac{3}{4}$ in. <i>A A</i> 24 oz. per ft.
$\frac{1}{2}$ in. <i>A A</i> 6 oz. per ft.	2 in. <i>A A A</i> ... 40 oz. per ft.
$\frac{1}{2}$ in. 8 oz. per ft.	2 in. <i>A A</i> 26 oz. per ft.
$\frac{5}{8}$ in. <i>A A A</i> .. 11 oz. per ft.	

Any size or weight per foot is made to order.

The length of a coil of lead pipe from $\frac{1}{4}$ " to 1" in diameter is usually about 60 feet, and the length of a bundle of lead pipe from $1\frac{1}{4}$ " to 2" in diameter about 36 feet.

Of course they can be obtained in longer lengths if desired. They can be purchased rolled up on wooden mandrels or

spools if desired, and this is a good method of preventing them from being "kinked" or damaged in shipment.

On account of the large diameter and the thickness of the metal of lead waste pipe, this pipe is never coiled. It is generally made in 10-foot lengths and shipped as straight tubes.

665. Lead pipe is very smooth on the inside, and offers the least resistance to the flow of water. It is easily bent to suit any situation, and easy curves are readily made. It is not suited to high pressures because of its small tensile strength.

Lead pipe varies greatly in quality. The pure lead is soft and pliable, and is particularly adapted for waste piping because it will stretch more equally, and will not tear or crack as quickly as a harder and more impure lead would while being worked into bends, etc. The hardness varies according to the kind and quantity of metals mixed with it. A hard, tenacious lead will stand more tensile strain than a softer lead. Therefore, no reliable estimate can be formed of the actual strength of lead pipe. It will bend under pressure without breaking, and is, therefore, desirable for connections to fixtures that are liable to change their position, in consequence of the settling or rocking of the building.

666. Lead, as a material for soil or drain pipes, is rapidly going out of use. The chief virtue of lead pipe is the smoothness of its interior surface, which enables waste matter to flow through it very easily.

It will not corrode internally to a serious extent if it be well ventilated.

Nearly all varieties of soil or earth will corrode lead pipe externally; therefore, it should not be used for underground drains.

It should not be enclosed by cement or mortar where it passes through a wall, without first being wrapped with tarred paper or other rot-proof material.

Lead soil pipes should not be less than $\frac{1}{4}$ -inch thick. Steam rapidly destroys lead soil and waste pipes, and

plumbing fixtures using hot water should not discharge into them. The alternation of hot and cold water will cause the lead to crack at the weakest point, usually at the supports.

If steam or very hot liquids are to be admitted to a drain, the pipe should be of wrought iron with screwed joints. The alternate expansion and contraction will strain and eventually destroy the calking in spigot and socket joints of cast-iron pipe.

667. Wrought-iron pipe is made either *black* or *galvanized*, and all American manufacturers conform the dimensions of the pipe to a standard list as follows:

TABLE 30.

STANDARD DIMENSIONS OF WROUGHT-IRON PIPE.

Nominal Internal Diameter in Inches.	Actual Internal Diameter in Inches.	Actual External Diameter in Inches.	Thickness of Metal in Inches.	Area of Internal Diameter in Square Inches.	Weight in Pounds per Lineal Foot.
$\frac{1}{8}$	0.270	0.405	.068	0.0572	0.243
$\frac{1}{4}$	0.364	0.540	.088	0.1041	0.422
$\frac{3}{8}$	0.494	0.675	.091	0.1916	0.561
$\frac{1}{2}$	0.623	0.840	.109	0.3048	0.845
$\frac{3}{4}$	0.824	1.050	.133	0.5333	1.126
1	1.048	1.315	.134	0.8627	1.670
1 $\frac{1}{4}$	1.380	1.660	.140	1.4960	2.258
1 $\frac{1}{2}$	1.610	1.900	.145	2.0380	2.694
2	2.067	2.375	.154	3.3550	3.667
2 $\frac{1}{2}$	2.468	2.875	.204	4.7830	5.773
3	3.067	3.500	.217	7.3880	7.547
3 $\frac{1}{2}$	3.548	4.000	.226	9.8870	9.055
4	4.026	4.500	.237	12.7300	10.728
4 $\frac{1}{2}$	4.508	5.000	.246	15.9390	12.492
5	5.045	5.563	.259	19.9900	14.564
6	6.065	6.625	.280	28.8890	18.767

Wrought-iron pipes are made in lengths from about 15 to 20 feet.

All wrought-iron pipe which is $1\frac{1}{4}$ inches or less in diameter is **butt-welded**; that is, the edges are joined as shown in Fig. 147.

All sizes above $1\frac{1}{4}$ inch are **lap-welded**, the edges being lapped as shown in Fig. 148.

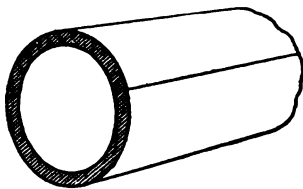


FIG. 147.

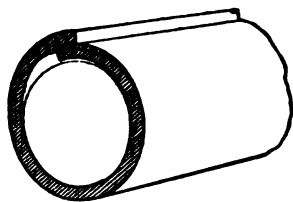


FIG. 148.

All butt-welded pipe is tested at the mills to a pressure of 300 pounds per square inch, and lap-welded pipe is similarly tested to 500 pounds pressure per square inch.

Wrought-iron pipes having a greater thickness of metal than those above are made, and are known as *extra strong* and *double extra strong*. The extra thickness of metal reduces the bore of the pipe; the outside diameter of each nominal size is never changed. Thus, all grades of pipe will connect properly with standard fittings.

668. Steel pipes are made in the same way and of the same sizes as wrought iron. They are being very extensively used on common work. Their durability, as compared with wrought iron, is, however, claimed to be less, and they are very destructive to the pipe-cutting and threading tools. Steel pipes are much more brittle than wrought-iron, and, consequently, can not be so conveniently bent.

669. Galvanized-iron pipe is suitable for the heaviest pressures, but it must be put together with screw joints. The short bends and sharp angles, incident to this mode of connection, cause much friction, and impede the flow of water.

670. Plain, or black, wrought-iron and steel pipe is subject to the same drawbacks, and it also rusts rapidly; it is very liable to clog by rusting internally.

671. Wrought-iron pipe, put together with screw joints, is coming into use in some quarters for drainage work, but its value for that purpose is still regarded as problematical. It appears to have some advantages. For instance, when once made tight, it will remain so. The number of joints is much less. In some situations, screwed joints can be made where socket joints can not be calked.

It is very rigid, and is able to stand upon an independent base, and thus be detached from the walls of the building, if desired. Its expansion and contraction due to changes in temperature, however, is somewhat more than that of cast-iron pipe.

All soil or vent pipes of cast or wrought iron should be coated outside and inside with hot asphaltum. This should be done at the mills, by the maker. The fittings for soil, vent, or drain pipes, of cast or wrought iron, should always be flush fittings, so that the bore of the pipe shall be uniform, without enlargements or pockets.

672. Brass or copper tubes are made of all diameters and thicknesses. The size by which these tubes are designated is usually the outside diameter, and the thickness of the metal must always be specified, in order to secure tubing which is suitable for the purpose in view.

Brass and copper tubes are made by two methods, and are accordingly designated as *seamless drawn*, or *brazed* tubing.

673. Seamless drawn tubing is made from a solid block of metal without a joint, and is much superior in strength to brazed tubing. **Brazed tubing** is similar in structure to butt-welded wrought-iron pipe, except that the joint is secured by brazing.

Brass tubing is also made in sizes which correspond in external diameter with the sizes of wrought-iron pipe, in order that it may be screwed into the same fittings that are

used for wrought-iron pipe, or for convenience in using the standard iron pipe tools.

674. The following table gives the approximate weight per lineal foot of iron pipe size brass tubes:

TABLE 31.

Nominal Diam. in Inches.	Weight per Lineal Foot in Pounds.
$\frac{1}{8}$	.25
$\frac{1}{4}$	.43
$\frac{3}{8}$	.62
$\frac{1}{2}$	.90
$\frac{3}{4}$	1.25
1	1.70
$1\frac{1}{4}$	2.50
$1\frac{1}{2}$	3.00
2	4.00
$2\frac{1}{2}$	5.75
3	8.30
$3\frac{1}{2}$	10.90
4	12.70
$4\frac{1}{2}$	13.90
5	15.75
6	20.60

675. Brass and copper tubes are smooth inside, and are made of any thickness. They are best for heavy pressures of 60 pounds per square inch or more. Below that pressure lead pipe may be used.

676. Wooden pipes are usually made from solid square timber. The bore is made by an auger which is forced throughout the length of the piece.

Another variety is made by winding a flexible wooden

strip or ribbon upon a mandrel spirally in such a manner that the layers overlap one another and then securing them together with cement. It is made of all diameters and of all lengths up to 20 feet.

677. Fig. 149 is a cross-section through a **wooden stave pipe**. The continuous pipe is made of staves, *a, a*, bound together by wrought-iron or steel hoops *b*, the ends of which are secured by means of nuts screwed against clips or shoes as at *c*.



FIG. 149.

The cross-joints of the staves are mortise and tenon as shown in Fig. 150. These joints do not continue around the pipe, but are placed to "break joint" in the length of the stave.



FIG. 150.

Wooden pipes carefully soaked in asphaltum are useful for conveying salt water and other liquids which have a corrosive effect upon metal pipes.

678. Cast-iron pipes for plumbers' use, commonly called **soil pipes**, are made with a **socket** on one end and a **spigot** on the other. They are made in two grades, the **standard** and **extra heavy**, the latter having the greater thickness of metal.

These pipes are made five feet long, exclusive of the socket, and may be had from two to twelve inches inside diameter. They are sold by the lineal foot.

Pipes having a socket on each end, called **double hub pipes**, are sold by the piece.

The above cast-iron pipes are used chiefly for the drainage of buildings.

Cast-iron pipes used for conveying water under pressure, such, for example, as pipes from a reservoir to a building,

are much heavier and longer than those for drainage purposes.

Cast-iron pipes may be had either **plain**, i. e., as they come from the mold, or **coated** with some particular material, such as asphaltum. In ordering this kind of pipe, it should be stated whether *plain* or *coated* is wanted.

679. Soil pipes should be made of cast iron not less than $\frac{1}{8}$ inch thick for diameters of 4 inches or less, nor less than $\frac{5}{16}$ inch for larger sizes.

For buildings under 65 feet in height, the *standard* grade may be used, but in buildings higher than 65 feet, *extra heavy* soil pipes should be used.

The same rule applies to vent pipes. These corrode much more than soil pipes, and metal is necessary to compensate for corrosion, quite as much as for strength.

680. **Earthenware drain pipes** are of various qualities as to texture, varying from a porous material like that of common red brick (sometimes called **terra-cotta**) to a hard and compact material which is glazed to make it water-tight, called **salt glazed** or **vitrified earthen pipe**. The latter class is made in two and three-foot lengths, and has a socket on one end. The sizes usually kept in stock by dealers are 3", 4", 5", 6", 7", and 8" inside diameters.

681. Earthen, or vitrified, pipes are suitable for underground drains only, and even for that use are inferior to the cast-iron pipes. They should never be used inside of a building, nor in any situation where the leakage from them can do any damage. They should not be used in the neighborhood of wells or cisterns, because they are so liable to crack and leak, and thus pollute the water in the soil for a considerable distance. They should not be laid in new or *made* ground, as this will settle with heavy rainfalls and the pipes will break. The pipes being so short, the number of joints is greater than with any other kind of pipe. *Plain*, or unvitrified, *earthen pipes* should only be used to drain wet ground. The vitrified, or salt glazed, pipe should be chosen to convey sewage.

MISCELLANEOUS MATERIALS.

682. Oakum is composed of fibers of hemp, which are made to adhere together strongly by moistening them with pine tar. It can be obtained in bales, either loose or slightly twisted.

683. Asphaltum is a native mineral pitch or bitumen, and is found in several localities in the United States, but the greater part of the supply is obtained from European sources. It is black or dark brown in color, and the fractured surfaces have a high luster. Its specific gravity is about 1.10. It melts and burns, leaving no residue, and it dissolves completely in petroleum or turpentine. For the purpose of making water-proof coatings on brickwork, etc., it is mixed with coal tar and put on hot. It is used for coating iron work of all kinds that is exposed to dampness, or is buried in soil. Pipes, etc., which are to be thus coated should be heated to the melting point of the asphaltum before they are dipped.

684. Plaster of Paris is used in the plumbing trade, chiefly for bedding or setting marble work; making joints about wash-basins, cocks, etc. It should be mixed in small quantities with water to the consistency of thick cream, and applied as quickly as possible, for it sets rapidly. It should not be disturbed while setting. It is very porous, and, therefore, is not suitable for making joints under water.

If plaster of Paris begins to set while it is being applied, throw it away and mix up a fresh batch. Do not attempt to thin it down with more water.

685. Portland cement is used by plumbers for many purposes, chiefly for jointing earthenware pipes. It should not be used in the pure state, but should be mixed with an equal quantity of clean, sharp sand, and then tempered with clean water into a thick mortar. If too much cement is mixed at a time it will begin to set before it can be applied. Portland cement should not be "*tempered up*," that is, thinned with water when it has begun to harden, for any purpose except for bedding or supporting the fireclay pipes.

This cement will set under water, and a barrel of it weighs about 400 pounds.

686. Rosendale cement is similar to Portland cement, but is not so strong, and is of an inferior nature. It should be mixed with sand, same as Portland cement, before being tempered with water. It is not suitable for jointing fireclay pipes or other work exposed to water. A barrel of this cement weighs about 300 pounds.

687. Glaziers' putty is made by mixing about seven parts of whiting with three parts (by weight) of boiled linseed oil. It is used for bedding woodwork around fixtures, and for bedding cast-iron sinks, etc.

688. Red lead is mainly oxide of lead, and is sold in kegs in the form of a heavy powder. It is prepared for use by mixing it in small quantities with boiled linseed oil just before using. It becomes very hard in setting, and is used to bed fixtures, and to set slate slabs, etc., but must not be used to joint marble work as the oil is absorbed by the marble and stains it.

689. White lead is a carbonate of lead ground to a fine paste with boiled linseed oil. It is the basis of nearly all good house paints, and is used by plumbers for the same purposes as red lead.

690. Plumbers' soil is composed of lampblack mixed with a small amount of glue and water. The surface to which plumbers' soil is to be applied should first be cleaned by rubbing with chalk, as it will not adhere to a greasy surface. It is probably cheaper to buy the soil than to make it.

FITTINGS FOR SCREWED PIPES.

691. Wrought-iron pipe connections are made by means of either cast-iron or malleable-iron castings which are provided with threaded sockets into which the pipe is screwed.

Cast-iron fittings are made with a band around each socket, as at *A* in Fig. 151, which shows two wrought-iron pipes *B* and *B* joined together by a *cast iron T* fitting.

The band around the socket strengthens the fitting

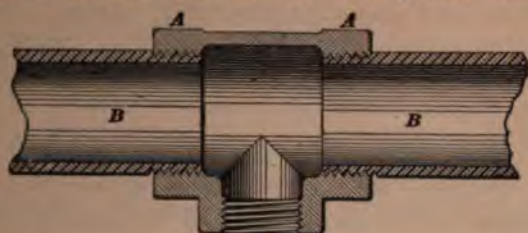


FIG. 151.

against the bursting strain which arises from the screwing of the pipe into the socket. *Malleable-iron fittings* are made with a *bead* around each socket, as shown by Fig. 152, the bead serving as a reenforcement.



FIG. 152.

692. Fig. 153 shows a *plain* malleable-iron fitting, known as a

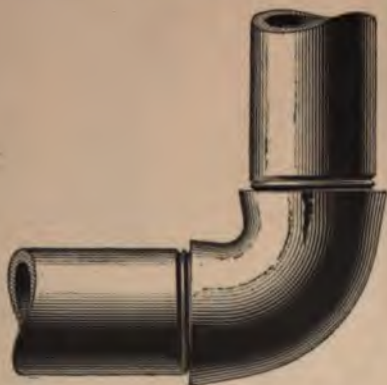


FIG. 153.

"quarter ell," or a 90-degree elbow, joining two pieces of iron pipe at right angles. The socket into which the horizontal pipe is screwed is swelled out, but otherwise is as perfect as can be made in such a fitting. The socket into which the vertical pipe is screwed is not only swelled, but is split in the swelling, as shown. The sockets swell and assume a permanent set because they are too weak to resist

the great tensile strains to which they are subjected when the tapered pipe threads are screwed into them. Neither of these joints is suitable for first-class work. Beaded fittings should always be used.

Brass fittings are also made for use with brass screwed pipe, and they should always be heavily beaded.

693. Fittings are of two kinds—*ordinary* and *flush*. The **ordinary fittings** are of larger internal diameter than the pipes which are attached to them, as shown in Fig. 151.

694. **Flush fittings** are so made that their internal diameter is the same as that of the pipes which are attached to them, and the joint is made between the end of the pipe and the shoulder at the inner end of the socket, as shown in Fig. 154. This prevents any irregularity in the bore of the pipe line, which is very desirable in all drainage work.

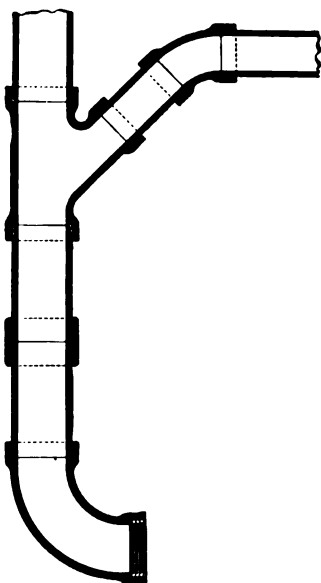


FIG. 151.

The tightness of the joint made with ordinary fittings depends upon the perfect filling of the thread in the socket by the thread upon the pipe. To facilitate this, both the socket and pipe ends are made conical. The proper taper, together with the number of threads per inch, are stated in detail in Art. 746.

It is customary to paint the thread on the end of the pipe with red lead mixed with boiled linseed oil, or some other cement, before screwing it into the socket. The paint lubricates the parts and allows the thread to be screwed up with a minimum expenditure of force. It also compensates for any irregularities in the threads by filling the interstices.

695. Unions are made in many forms. Their duty is to join together the ends of two pipes where it is not suitable to turn either one, or in places where it may at some future time be desired to disconnect the pipes without cutting them.

Unions are of two kinds—the *flanged* and the *screwed*. The **flanged union**, shown in Fig. 155, is used principally on wrought-iron pipes having a diameter of two inches or

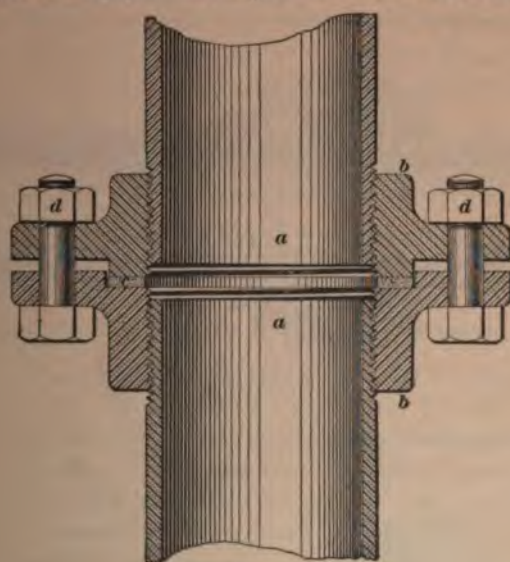


FIG. 155

more. The pipe ends *a* and *a* are screwed into the flanges *b* and *b*. The leather washer *c* is placed in position between the flanges, and then compressed by screwing up the nuts *d* and *d*. This draws the flanges together and makes a water-tight joint. Care must be taken to have the flanges faced equal all around so that the pressure upon the washer will be uniform.

The **screwed unions** are of two kinds—the *ground*, Fig. 156, and the *packed*, Fig. 157. In the **ground unions** the cone *a* and the socket *b* are ground to a perfect fit, and are drawn together by the nut *d*. The collar *c* must be turned

true with the axis of the cone, and the axis of the screw thread must also coincide perfectly with that of the cone, otherwise it will be difficult to draw the joint together with sufficient accuracy to make a tight joint. The joint is made tight by the fit of the parts rather than by the pressure put upon them. Therefore, if the joint is not tight, do not attempt to make it so by straining the nut *d*, but rectify the fit of the parts. Ground unions are best adapted for pipes which convey hot water.

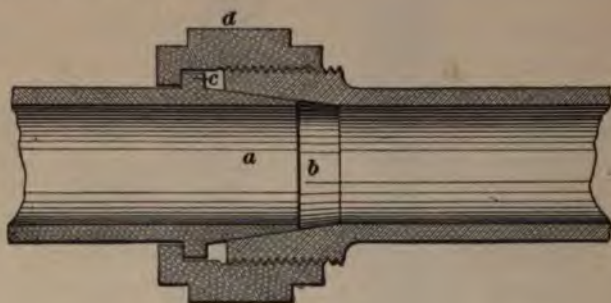


FIG. 156.

In the **packed union**, shown in Fig. 157, the joint is made by compressing the washer *e*, which is made of leather, or of rubber compounds.

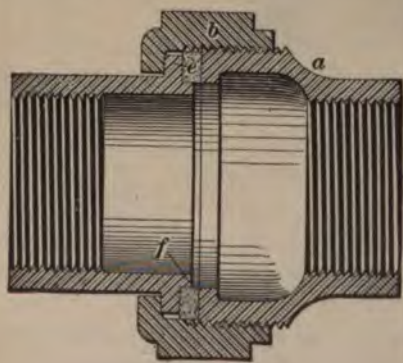


FIG. 157.

To prevent the soft washer from getting out of place, one-half of the coupling is frequently made with a projecting ring *f*.

The union ring *b* which draws the halves together by being screwed over the half *a*, is in the form of a hexagon, so that a wrench may be used for screw-

ing up the joint. Screwed unions are used chiefly on pipes having a diameter smaller than 2 inches.

INSPECTION OF MATERIALS.

696. All materials should be inspected when received and before accepting them.

697. Black sheet iron should be examined for flaws or holes on its surface, for equality of thickness, and as to its liability to crack if bent sharply either with or across the grain.

698. Galvanized sheet iron should be examined for the same defects as black sheet iron. The zinc coating may be tested by bending the iron at a temperature of about 60° or 70° F. If the zinc adheres properly to the iron it will not scale or peel off.

699. Sheet copper, sheet lead, and sheet zinc are generally accepted as they are placed upon the market.

700. Lead pipe should be soft and pliable. Examine for kinks, bruises, and punctures caused by rough handling during shipment. Otherwise, it is placed on the market in good condition and requires no further inspection.

701. Tin-lined lead pipe should have its interior surface examined, if possible, to see if it *is* tin-lined. Shave off the end of the pipe square and clean, and ascertain the thickness of the tin lining by breathing on the highly polished end. The breath will discolor the surface of the lead with a thin blue coating, and the tin will remain bright. The thickness of the tin lining will thus become visible.

702. Block-tin pipe, like lead pipe, is generally accepted as reliable in the form placed upon the market. Pure block tin may be detected by a peculiar crackling noise it makes when being bent at ordinary temperatures.

703. Seamless brass tubing should have an equal thickness all around, and should be slightly annealed to prevent its being too brittle for working.

704. In brazed brass and copper tubing the brazed seams should be examined carefully. It should be uniformly loaded with hard solder and thoroughly *sweated*. If possible, examine both the inside and outside of the seam.

The best and strongest form of brazed seam is *dovetailed*. (See Fig. 227, *D*, Art. 807.) Lap or butt-brazed seams are liable to warp in the process of brazing, and are not very strong.

705. Galvanized-iron pipe placed upon the market is usually accepted as good. Sometimes, however, it is partly choked by the zinc used to galvanize it clogging in lumps. This may be detected by rolling a marble a size smaller than the pipe through its entire length, or, if possible, by looking through it. The quality of the galvanizing may be observed by bending the pipe at an ordinary temperature, to an easy bend. If the galvanizing is good it will remain intact. Galvanized-iron pipes are liable to be quite brittle, but this brittleness does not seem to affect the durability of the pipe. The ductility of galvanized-iron pipes is less than that of black iron, and sometimes is so low that if the pipe is bent successfully it can not be bent back without breaking.

706. In wrought-iron pipe (black) the welded seam which runs the whole length of the pipe should be examined. A good welded seam is scarcely visible, and the pipe should have a smooth external and internal surface. The pipes should be straight and the threads cut clean.

707. Wooden pipes should be examined for knots, splits, and cross-grained wood, as these weaken the tube.

708. Cast-iron drain and soil pipes should be examined for sand holes in the metal or splits in the pipe. A fracture can be detected by tapping the pipe with a chisel or small hammer. If the pipe is sound it will ring clearly when struck, and if cracked it will give a dull, harsh sound.

Sometimes the *core* will shift when a pipe is being cast, particularly if the pipe is cast horizontally, in which case the core is liable to rise in the middle. This will cause the metal to be thicker at the bottom than at the top of the pipe. Irregularities in thickness can be detected by irregularities of the sound when rapped with a hammer at various points.

Flaws, or places where the metal has not flowed together

and become properly united, can be detected by sounding the pipe with a hammer or by its appearance.

709. Earthen drain pipes are liable to warp and twist in firing. They should be examined for an equal caliber, smooth-glazed internal and external surface, and particularly for cracks around the back of the socket and irregularities within the socket. Pipes having broken or crooked sockets should be rejected.

710. Fittings for wrought-iron and brass pipe should be inspected for sand holes and flaws, and it should be seen that the screw threads are deep and full.

711. Fittings for cast-iron drain pipes should be examined for sand holes, splits, and other flaws, and for lumps and other obstructions to the free flow of sewage through them.

712. Fittings for earthen pipe should be examined for irregularities in cross-section, or caliber, cracks, protruding pieces of salt glaze, abrupt turns, etc. The sockets should be examined to see that they are round and of proper depth.

TOOLS.

713. The tools commonly used for plumbing are as follows:

The **hand saw** shown in Fig. 158 is used for cutting leaden pipe, wood, etc. It should have a blade about

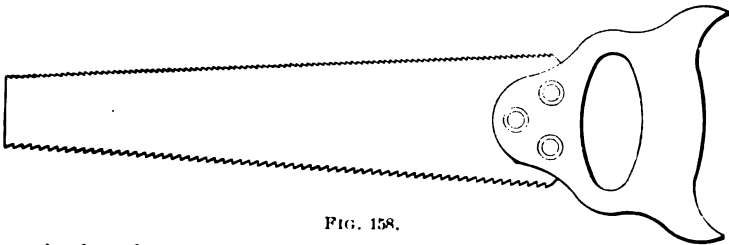


FIG. 158.

16 inches long, and should have coarse teeth upon one edge and fine teeth on the other.

714. The **hack saw** shown in Fig. 159 is used for cutting all metals except hard steel. The blade *B* is held

in place by the small pins *a* and *b*, located, respectively, in the shank of the handle and the threaded pin *D*. Blades for hack saws are of two different kinds—*hard* and *tempered*. The hard ones may be used for cutting all metals except hard steel, but it is better to use them only on the harder metals, such as cast iron, wrought iron, soft steel,

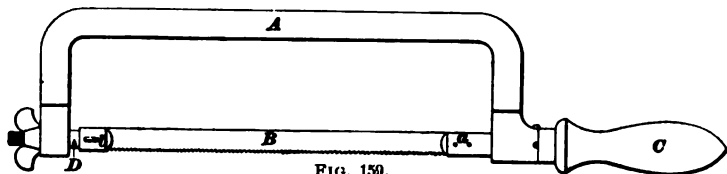


FIG. 150.

etc. The tempered blades are used only for cutting the softer metals, such as lead, zinc, and brass, either in bars, sheets, or tubes. The hard blades break very easily, and extreme care must be taken when using them to move the saw back and forth without hugging the sides of the metal, as the least twist will break the blade. A new hard blade should never be used for cutting thin tubes and sheets, as this will break out the teeth quite rapidly. It is better to use a half worn-out blade in such cases.

715. Rasps are chiefly used for beveling sheet lead and pipe when preparing them for soldered joints.

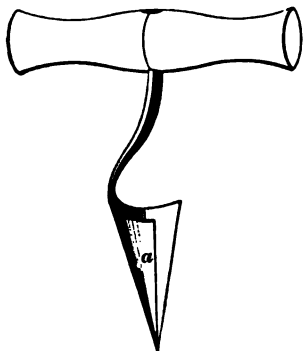


FIG. 160.

716. Files are used for shaping brass and iron, and for clearing the oxide from the soldering bits. A convenient size is a 12-inch *bastard cut* file.

717. The **tap borer** shown in Fig. 160 has a short conical bit *a* sharp on both edges, by which holes may be made and opened out in lead pipes or sheets. The bit should be quite short so that the point will not strike the back of a pipe when making a hole in the front side of it.

718. The **bending pin** shown in Fig. 161 is made of



FIG. 161.

steel, and is used for curving small pipe, and for working up the edges of holes which have been bored with the tap borer, etc.

719. The **turn pin** shown in Fig. 162 is a cone made of boxwood, and is used for expanding the ends of lead pipe.



FIG. 162.

720. The **shave hook** shown in Fig. 163 consists of a steel blade *A*, beveled to an edge all around, and



FIG. 163.

secured to a convenient handle. They are made of many shapes; that shown in the figure is for general use.

721. Soldering bits are of two forms, the *pointed bit*, shown in Fig. 164, and the *hatchet bit*, shown in Fig. 202, Art. **782**.

They consist of a block of copper *A*, which is secured to a convenient handle. The

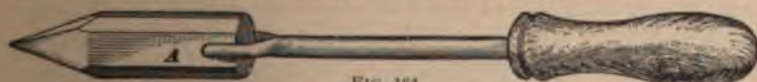


FIG. 164

shape and weight of the bit are varied to suit different kinds of work.

722. The **dresser** shown in Fig. 165 is made of boxwood. It is used for working sheet lead and lead pipe. Iron being harder than lead, tools made of this metal mark and bruise lead; consequently, wooden tools are used instead

of iron ones for hammering or beating lead into various shapes.

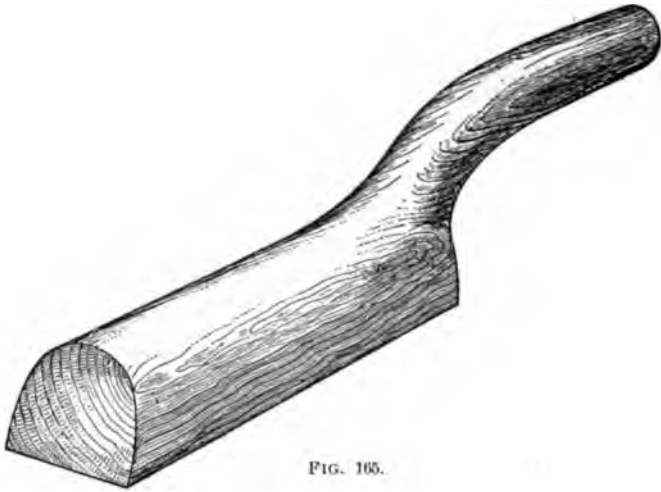


FIG. 165.

723. The **tank iron** shown in Fig. 166 is a valuable assistant in maintaining the heat which is required in making large wiped joints, and in wiping the seams in lead-lined tanks, etc.



FIG. 166.

724. In Fig. 167 is shown a cross-section of a **gasoline torch** which is extensively used by plumbers for applying heat to heavy brass or copper bodies before wiping; also for maintaining a working heat on large wipe joints or tank seams, and for thawing frozen pipes, etc. It is a very handy tool, and should be in every plumber's shop.

It consists of a brass chamber or body *a*, having a filling hole at *b*, which can be made air-tight by a movable brass screw plug and soft rubber washer. Near the bottom and passing through the body *a* is an air pump, the cylinder *c* of which extends into it as shown. The inner end of the cylinder has a small hole in its center, against which a **soft**

rubber washer *f* is forced by the spring *g*, which moves in a brass cylindrical guide *h*, perforated around its inner end as shown. The perforated tube *i* holds the cylinder *e* of the air pump rigid so that the valve *f* may always find its proper seat. The piston rod *c* of the air pump is a hollow brass rod having a brass knob or handle screwed on its outer end and a piston which forms a single-acting valve on its inner end. This piston, or single-acting valve, consists of a soft cup leather *d*, held in position by the cylinder *e* and by a small

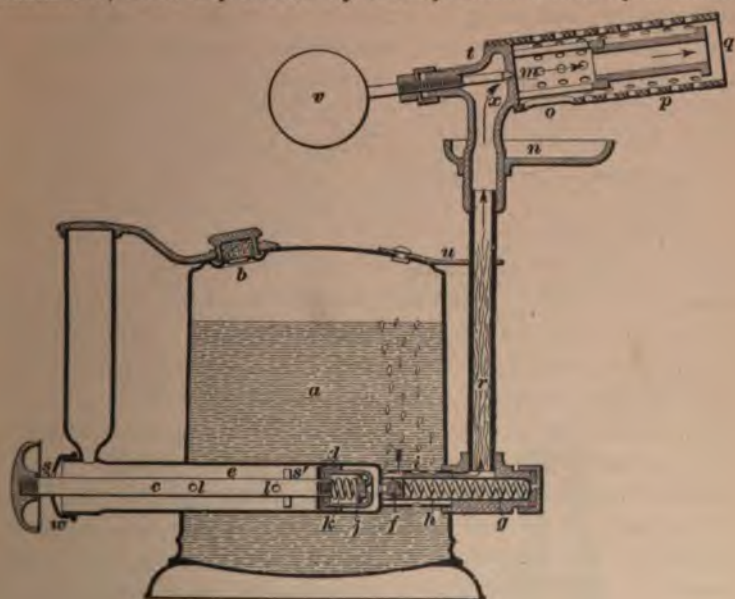


FIG. 167.

brass chamber as shown, which encloses a soft rubber safety valve *j*, held against its seat by a spring *k*, the tension of which is greater than that of the spring *g*. The cast brass burner *t* is attached to the lamp chamber *a* by a $\frac{1}{4}$ -inch wrought-iron tube, in which a lamp wick filter *r* is placed. The burner is secured by a brass stay *u* riveted to the top of *a*. A needle valve composed of a wooden knob *v* attached to a steel needle-pointed stem fits a small hole at *m*. A cast-iron cup *n* is attached to *t*, and a perforated wrought-

iron cylinder p having a large oval hole o is also attached to l .

The chamber a of the torch is nearly filled with gasoline having a specific gravity of about .75 through the filling hole b , which is then sealed air-tight with the screw plug. The piston rod of the air pump is then operated. While the rod is being pulled out the soft cup leather will collapse sufficient to allow air to enter the inner end of the pump cylinder. When the piston is pushed in, this air will be compressed, and when it attempts to return by way of the cup leather it will expand the leather against the sides of the cylinder; it then opens the valve f and escapes into the gasoline chamber a , where it rises to the top as shown, and increases the pressure in a . When the pressure in a , added to that exerted by the spring g , equals the force exerted by the spring k , the safety valve j will open and allow the air to be forced through the piston rod and out of the holes l, l , thus making it impossible to raise the pressure in a to a dangerous point. When sufficient air has been pumped into a the pin s near the knob is pushed inside the cap w through the small hole in it, and the knob given one-half turn. The pin will then keep the piston rod in place and prevent its being broken or otherwise injured. If the needle valve be now opened by turning the knob v to the left the liquid gasoline will be forced out of m by the compressed air in a . If the valve is opened a little, the liquid will flow into the cup n , but if it is opened too much it will squirt out of the orifice q . When the cup n is full, close m and ignite the liquid in n , which will burn with a smoky yellow flame and heat the burner and convert the liquid into a vapor. When the burner is hot enough, that is, when the liquid in n is nearly consumed, open m ; the gasoline vapor will ignite, and an intensely hot flame will be ejected from the orifice q . That part of the burner within the wrought-iron cylinder p conducts heat to the gasoline contained in the space x of the burner, and thus maintains a temperature sufficient to vaporize the liquid before it reaches the needle valve. Air entering the hole o and the perforations in p mixes with the

vapor and causes it to burn with a pale blue, smokeless and non-luminous flame.

The filter *r* fulfils a double purpose. It prevents dirt from entering the needle valve, and also prevents a back passage of flame to the gasoline chamber, which would



FIG. 168.

otherwise be liable to cause an explosion when the oil is low and the compressed air, which is highly saturated with gasoline vapor, is forced out of the burner.

The most desirable forms of gasoline torches are those which have their burners so constructed (hollow) that the gasoline must pass through their hot parts and become vaporized before it reaches the needle valve opening, even if the torch flame is reduced down very small.

725. The **blowpipe** shown in Fig. 168 is a slender, tapering tube, terminating in a fine jet orifice. It is usually made of brass, and the end having the smaller diameter is generally turned at about a right angle to the body of the pipe. These pipes are used in connection with an **alcohol lamp** made for the purpose, shown in Fig. 169, the air being supplied from the mouth of the operator.

The knack of keeping up a continuous blast and breathing easily while doing so is easily acquired. It consists briefly in breathing solely through the nostrils; the cheeks being



FIG. 169.

expanded to their full capacity are then contracted by muscular force so that they operate as a bellows, while the lungs are taking in air. The ordinary blowpipe is used for light soldering, where the copper bit is too clumsy.

726. The **ladle** is shown in Fig. 170. It is used for pouring solder in joint-wiping, and pouring lead in making joints in cast-iron pipes. For convenience it should have

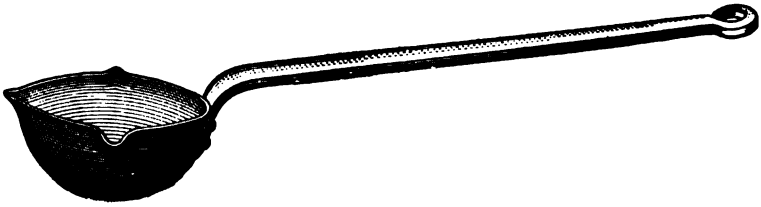


FIG. 170.

three lips, so that its contents can be poured to the right, left, or ahead, and thus work readily in all situations.

727. The **solder pot** is made of cast iron, and for ordinary jobs it should hold about 15 pounds of melted solder.

728. Wiping cloths are made of moleskin cloth or bedticking, of all sizes and thicknesses. They may be made by the workman, or may be purchased from dealers in plumbers' supplies.

The sizes commonly used are about as follows:

For $\frac{1}{2}$ " and $\frac{3}{4}$ " pipe,	$3\frac{1}{2} \times 4$ inches,	6 layers of cloth.
For 1" pipe,	$4 \times 4\frac{1}{2}$ inches,	8 layers of cloth.
For $1\frac{1}{4}$ " and $1\frac{1}{2}$ " pipe,	$4\frac{1}{2} \times 4\frac{1}{2}$ inches,	8 layers of cloth.
For 2" pipe,	$4\frac{1}{2} \times 5$ inches,	8 layers of cloth.
For 3" pipe,	5×6 inches,	8 layers of cloth.
For 4" pipe,	6×7 inches,	8 or 10 layers of cloth.

By practice, however, the plumber soon decides upon the proper size of cloth best adapted to his methods of solder manipulation.

729. Fire pots are made of various forms, to suit different fuels. Large iron *chaffers* are specially designed for burning *soft coal*. Fire pots for *charcoal fuel* are commonly made of sheet iron, but they do not last long.

In Fig. 171 is shown a cast-iron **charcoal fire pot** specially adapted to heating pots of solder or lead. Char-

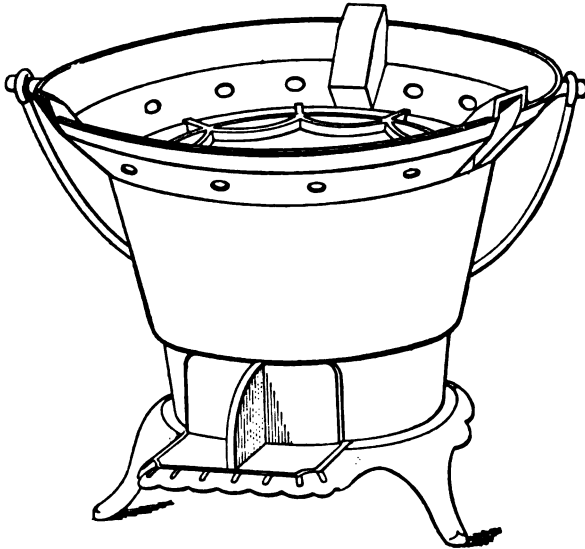


FIG. 171.

coal fire pots should be so constituted that the fire can be smothered when not in use.

Care must always be taken to protect the floor under a fire pot from being scorched or set on fire. Charcoal is a convenient fuel to use, but it has drawbacks that must not be overlooked. It will throw sparks and pieces of red-hot coals, which are liable to set the building on fire. Currents of air or a puff of wind will carry the sparks, which may do great damage.

The unburned charcoal is liable to be trodden into the floors, thus disfiguring and injuring them. It gives off large quantities of carbonic acid gas while burning, and

makes it necessary to ventilate very freely the room in which it is used.

730. In Fig. 172 is shown a cross-section of a **gasoline fire pot** extensively used by plumbers for heating solder and

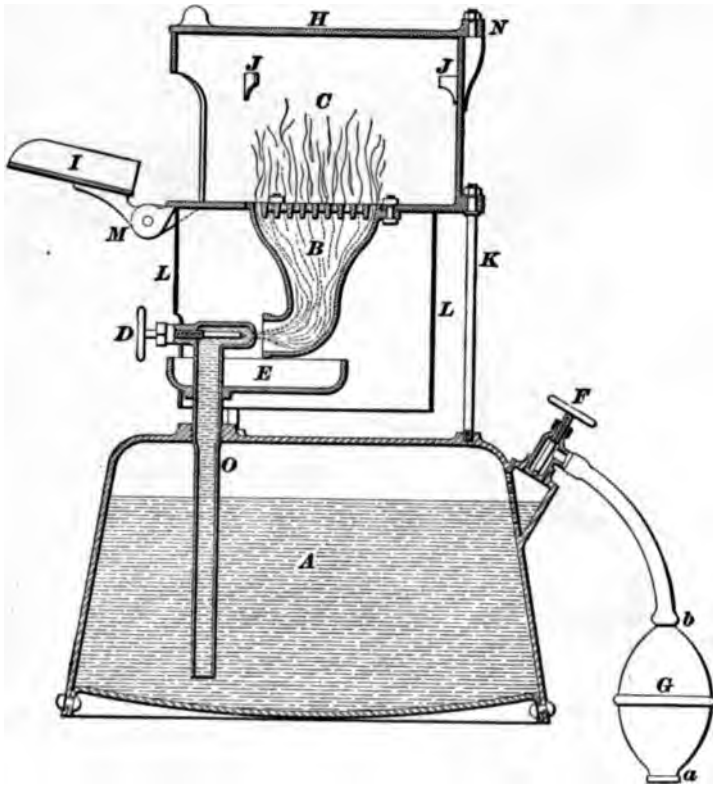


FIG. 172.

lead pots, soldering irons, etc. It is easily carried around, is clean in operation, and is perfectly safe if handled intelligently. It has largely superseded the charcoal fire pot, particularly in jobbing work. It is composed of an oil tank *A* made of steel or sheet iron, having a strong *curved* bottom. A feed tube *O*, having a needle valve *D* and a cast-iron cup *E*, is screwed to the top of the tank *A*. The feed-pipe is also

provided with a wick filter similar to the feed-pipe of Fig. 167. It is absolutely necessary that every gasoline fire pot and torch have a suitable filter as a safeguard to prevent the flame from flying back into the oil tank. A cast-iron mixing chamber *B* is secured by bolts to the bottom plate of the fire chamber *C*, which in turn is supported upon the top of *A* by three or four iron bolts *K*.

The fire chamber has cast-iron sides, a cast-iron door *I* hinged at *M*, and a cast-iron cover *H* hinged at *N*; also, three or four iron lugs *J, J*, so situated as to support the solder pot at a distance of about $\frac{1}{2}$ inch above the grating. A sheet-iron shield *L* encircles the burner, mixing chamber, and oil cup. A needle valve *F* is also screwed into a special socket piece brazed on the chamber *A*, and is connected by a rubber tube to a rubber-bulb air pump *G*, which has an inlet check-valve at *a* and an outlet check-valve at *b*. The operation of the furnace is similar to that of the gasoline torch already explained.

When the rubber bulb *G* is squeezed flat with the hand, the air it contains is forced through the check-valve *b*, rubber-tube connection and needle valve *F* into *A*. When the pressure of the hand is relieved, the check-valve *b* will close. The pressure of the atmosphere will cause the air to enter the bulb through the check-valve at *a*, forcing the bulb to assume its natural form, and, by another flattening of the bulb, the air will be forced into *A*. In this manner the pressure in *A* is increased until it is impossible to raise it higher with this form of a pump. Care should be taken not to attach any more powerful air pump to the oil chamber, as it is usually constructed just strong enough to suit the rubber-bulb pump, and is not provided with a safety valve, to prevent an excess of pressure.

When the needle valve *D* is opened, liquid gasoline will flow into *B* and drop into the cup *E*.

When *E* is full, *D* is closed and the liquid in *E* is ignited, heating the burner and mixing chamber *B*. When the gasoline in *E* is all consumed and the flame extinguished, *D* is opened and the gasoline vapor ignited as it enters the fire

chamber *C*. If the proper proportion of air is admitted at the lower orifice of the mixing chamber *B*, the gasoline vapor burns with a pale blue and smokeless flame, which is intensely hot.

If the flame appears languid and yellow, it shows that the supply of air is deficient—probably the air inlet is choked with dirt or soot. If the burner puffs and blows back to the point of the valve and burns there, it indicates that too much air is admitted in proportion to the amount of gasoline vapor which is generated in the burner.

It is necessary that the gasoline be completely vaporized before it reaches the burner, and that it never passes through the burner as a liquid, nor even as a mixture of gas and liquid.

The needle valve *D* is maintained at the proper temperature to vaporize the gasoline in various ways. The one shown in the figure is maintained by the heat radiated from the hot plate which forms the bottom of the fire-box and by protecting it from cold drafts by the shield *L*; this, however, is too uncertain and is not recommended. In the best forms of gasoline furnaces the feed tube passes around or through the flame, so that if the flame should be turned down low, sufficient heat will still be absorbed to convert the gasoline into vapor before it reaches the burner.

731. The **danger** to be feared in using gasoline furnaces is that the gasoline may reach the burner in the liquid state instead of in the condition of vapor. For instance, if a pot of solder is put on to be heated, and the workman is called away temporarily, to prevent the solder from burning while he is gone he turns the flame down, but not out. The burner thus cools off considerably, and, in consequence, fails to vaporize the entire amount of the gasoline which comes up through the feed tube, and, therefore, some liquid gasoline passes through the burner, which is ignited. It expands enormously when burning, running over the edges of the cup *E*, down onto the oil chamber *A*, and onto the floor.

The heat from this burning liquid rapidly generates pressure in the chamber *A*, which drives more gasoline through the burner. If not promptly extinguished, the floor will be flooded with burning gasoline, and the pressure will prob-

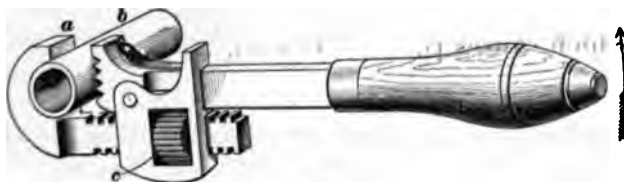


FIG. 173.

ably rise so high in *A* that it will explode. The fumes of gasoline rapidly mix with the air of the room and form an explosive mixture, and the result is not only an explosion of the apparatus, but usually a conflagration of the building.

Therefore, do not leave a gasoline fire pot while it is burning; if you must go away, extinguish it first.

732. Pipe wrenches similar to that shown in Fig. 173 are used for gripping iron pipes or other round bodies, such as bolts, etc., and form a lever by which the workman can turn the pipe or bolt into fittings, etc. The jaws *a* and *b* of these wrenches have teeth, as shown, which are caused to grip a round body placed between them by turning the nut *c*. The wrench is turned in the direction shown by the arrow, and the more force required to turn it the tighter will the jaws grip the body placed between them. This form of wrench is most suitable for pipes having diameters less than 3 inches. For larger pipes than this, the **chain tongs** shown in Fig. 174 are mostly used. This consists of two jaws *a* and *a'*, having sharp teeth on both sides, firmly secured to one end of a long bar of iron or handle *c* as shown. Between the jaws at *c* is fastened one end of a

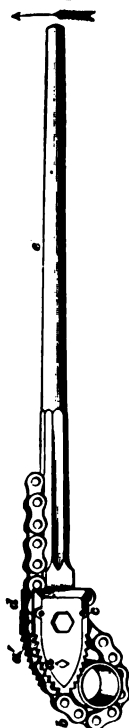


FIG. 174.

chain *b*. When the tongs is to be applied, the chain is passed around the pipe as shown, and its loose end is slipped into a link socket at *d*. The handle *e* is then pulled in the direction of the arrow, which causes the pipe to turn with it.

733. Pipe vises are used for holding a pipe rigid while the pipe is either being cut or having a thread cut on its end. A common form of pipe vise is shown in Fig. 175, in which two hardened steel jaws *a* and *a'* having teeth are made to grip the outer surface of a pipe placed between them by turning the handle and thus operating the screw. The vise is secured to a work bench or some other solid support by means of either lag-screws or bolts and nuts. In the figure the vise is shown to be open, that is, the upper frame *d* is swung up around the center *c*, which forms a hinge. When it is to be used *d* is swung down and is secured

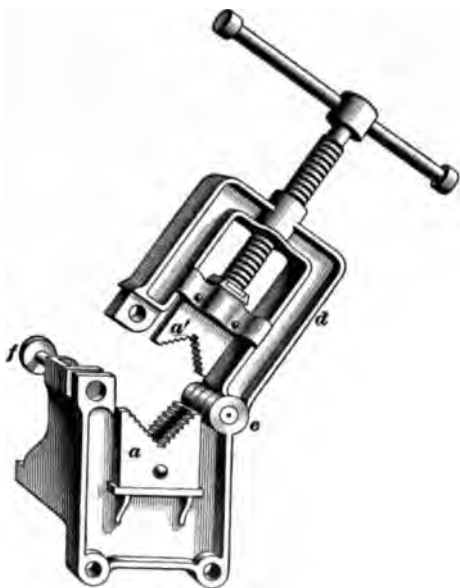


FIG. 175.

by the pin *f*. Pipe vises are made of malleable iron and steel, and the teeth of both the pipe vises and pipe wrenches should be kept sharp. If they become too dull they will slip and cut a furrow around the pipe, and thereby weaken it; besides, it conveys the impression of bad workmanship.

734. Pipe cutters are tools used for cutting wrought-iron pipes. These cutters are made of various shapes and sizes. A very common form of pipe cutter is shown in Fig. 176, which is called a **three-wheel cutter**. In this two knife-edge hardened

steel wheels *a* and *b* are pivoted to a malleable-iron casting *c*, and a third *d* to an arm *e*, which in turn is hinged at about the center of the casting *c*, as shown. The other end of the casting *c* is provided with a long boss and is tapped out to receive a handle *f*, so that by turning this handle the wheel *d* and the arm *e* may be caused to move.

In cutting a pipe it is first secured in the pipe vise, and then the cutter is slid over the pipe, and the wheels *a*, *b*, and *d* pressed against it by turning the handle *f*. This causes the wheels to sink into the softer metal which forms the pipe and spread the molecules apart without cutting out. The cutter is then pulled by its handle *f* around the pipe, which causes the wheels *a*, *b*, and *d* to revolve, and thereby cut a deep groove around the pipe. After the cutter has been pulled around the pipe a few times the handle *f* is turned a trifle more, and the cutter is then pulled around the pipe as before. This is continued until the pipe is cut. Oil should be used freely in cutting pipe, and the wheels of the cutter should be kept sharp, since, if their edges are dull



FIG. 176.

they will not wedge apart the metal forming the pipe, but will force part of it inwards, thereby reducing the bore of the pipe at this point by forming an *arris* or *burr* which will reduce the flow of water through the pipe.

735. Reamers are used chiefly to remove the *burrs* from the cut ends of pipes. These tools are conical in shape, and if they are properly proportioned to facilitate easy entry of water into the pipe, that is, to overcome the effects of the contracted vein, the length of the reamer or the altitude of the cone will be twice the diameter of the base, as shown in Fig. 177.

The convex surfaces of reamers are formed into a series of sharp teeth converging towards the apex. By pressing the reamer into the orifice of the pipe and revolving it, the

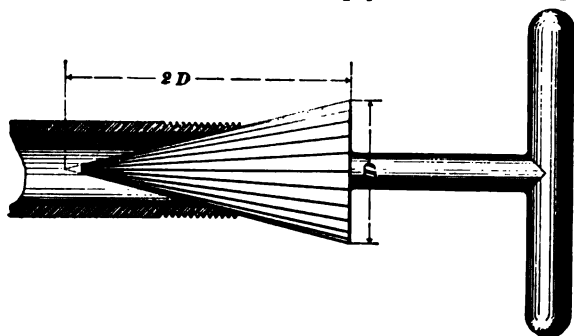


FIG. 177.

teeth cut off the burr and form the internal surface at the orifice into a frustum of a cone.

736. Stocks and dies, shown in Fig. 178, are used for cutting threads over the ends of wrought-iron and brass pipes. They are made of various shapes and sizes. The dies (*a*) and (*b*), also shown in the sectional view, are those parts which, on being pressed against the plain end of the pipe and revolved, by means of the stocks in which they are held, will take hold and cut a V-shaped screw thread over the end. Dies are either *solid* or *adjustable*. The solid die is generally used only for small pipes, and the adjustable for the larger ones. Two forms of **solid dies** considerably used are shown at (*a*) and (*b*) in the figure; (*a*) is made of one piece of tool steel having four sets of cutting edges *a*, as shown, and (*b*) is made of malleable iron except the *teeth* or *chasers* *a*, which are of tool steel and set in the malleable-iron frame as shown. The die (*b*) admits of the renewing of the teeth or chasers when they are worn, and is used for somewhat larger pipes than (*a*).

Dies vary in thickness with the diameter of pipe to be threaded, being thinner for the smaller pipe. Solid dies cut the full depth of the thread by one operation, which wears them out rapidly, and on the larger sizes of pipes makes it

very laborious to cut a thread. To overcome these objections the **adjustable** or **split die** has been made. These dies are composed of two or more parts so arranged that

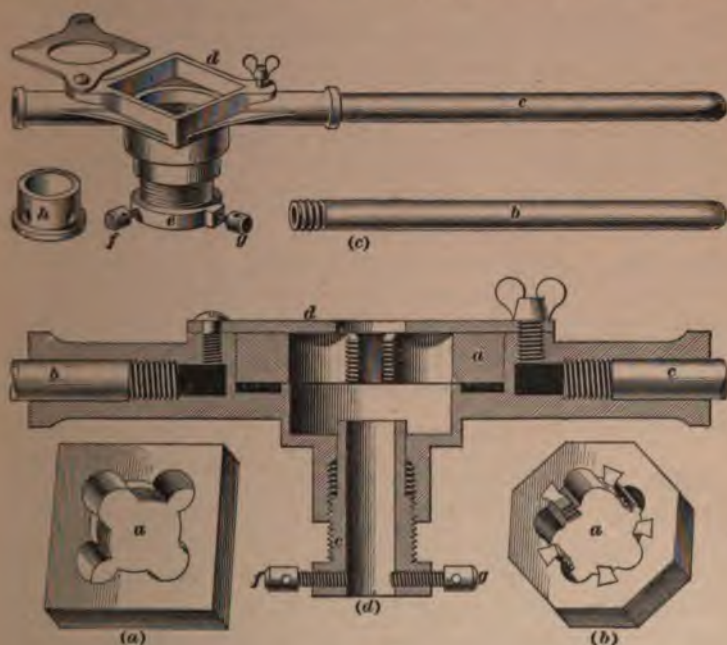


FIG. 178.

they can be opened or closed to cut a thread on a number of different sizes of pipe, also to cut out a little of the thread at a time or to cut a thread by a number of operations instead of by one, as the solid die does.

737. The **die stock** shown in perspective at (c) and in section at (d), Fig. 178, is that part which holds the die solid and at right angles to the axis of the pipe on the end of which a thread is to be cut. It consists of two iron bars or handles *b* and *c* screwed into a malleable-iron casting *d*, in which the die is placed as shown at *a* in the sectional view (d). That part of the casting *d* which is slipped over the end of the pipe is supplied with a guide *e*, which moves in a

threaded socket, the threads of which have the same pitch as those of the thread to be cut by the die. The guide is provided with three or more set-screws *f*, *g*, etc., which, when screwed down on the pipe, rigidly clamp it and prevent the guide from turning, and when the stock is revolved they at the same time pull the die against the end of the pipe on which the thread is to be cut, and thus give it a start to cut the thread. It is evident that the largest diameter pipe on which a thread can be cut with a stock is one whose outside diameter is equal to the diameter of the hole in the guide. To facilitate the threading of smaller pipes than this, a bushing *h* is used whose inside diameter is equal to that of the pipe, and whose outside diameter is equal to the inside diameter of the guide, the bushing being held in place by the set-screws *f*, *g*, etc. The bushings and dies are changed according to the diameter of the pipe to be threaded.

738. Threads on pipes two inches and less in diameter are usually cut with the ordinary hand stocks and dies shown by the last figure. Those of larger diameters are usually cut with special *threading machines*, which work with a crank. The power on the handle of the crank is multiplied by gear-wheels and the speed of the dies is correspondingly decreased. In cutting threads on wrought-iron pipes, machine oil should be freely poured on the pipes at the points where the dies are cutting. This cools the pipe and the teeth of the dies, and also lubricates the parts. It prevents the pipe from overheating and expanding, and the dies from *losing their temper* and becoming soft and dull.

When it is necessary to thread a piece of pipe which is too short to be held in the vise, a *nipple chuck*, or *nipple holder*, is used. This is simply a pipe coupling screwed over the end of a piece of pipe long enough to hold in the vise. The short piece, or nipple, should be screwed into the coupling until it *butts* against the end of the longer pipe, as this prevents swelling and splitting of the coupling.

CUTTING PIPE.

739. Wrought-iron pipe up to two inches in diameter is commonly cut by means of the wheel cutter already described.

The cut ends should be examined to see whether any cracks or splits have been started by the cutting operation.

Pipes that are to be screwed into flush fittings and make butt joints must have their ends squared after they have been cut, either in a lathe or in a suitable cutting-off machine. Unless the end is perfectly square with the axis of the screw thread, it will be impossible to make a good joint against the shoulder of the fitting into which it is screwed.

When cutting pipe which is *coated internally* with enamel or glass, great care should be taken to avoid chipping or cracking the coating or lining. The wheel pipe cutter should not be employed to cut this class of pipe. The only kind of cutter which may properly be used is one which cuts like a lathe tool, leaving the end of the pipe square and true, and does not crack or peel off the brittle lining.

The larger sizes of wrought-iron pipe should be cut off either in the lathe or by a cutting-off machine. When they must be cut by hand a **cape chisel** or **gouge** should be used to cut a groove around the pipe, the direction of the hammer blow being nearly tangential to the surface of the pipe. A *cold chisel* should not be used, because the direction of the blow is towards the center of the pipe, and the pipe is so elastic that the force of the blow is largely wasted. It also tends to crack and split the pipe.

740. To cut a cast-iron soil pipe, it should be laid upon a mound of earth, if practicable, rather than upon a stone or block of wood. Either a cape chisel may be used to cut a groove around the pipe or a thin sharp cold chisel in the manner shown in Fig. 179.

The chisel *a* should not be held square with the pipe, but should be inclined at an angle towards its end, the object being to chip a **V** groove around the pipe. At every blow of the hammer the chisel should either be shifted or the pipe turned. Thus, an expansive strain is set up all around the pipe, and

care must be taken that the strain is equal throughout the

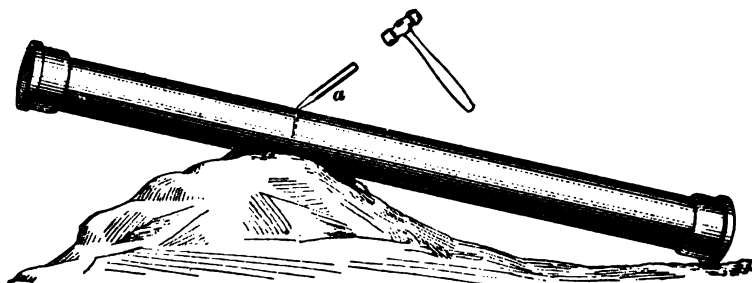


FIG. 179.

entire circumference, otherwise the pipe is liable to crack at the point of greatest strain.

BENDING PIPE.

741. Lead pipe of the grades *A A A*, *A A*, *A*, or *B* may be bent over the knee or over a rounded block without materially distorting the circular section of the pipe unless the bend is a very short one, in which case care must be taken to prevent the pipe from kinking or flattening sideways. Large pipes and those made of thin material may be bent by filling them with dry sand and thoroughly ramming it in order to avoid kinking.

There is an objection to bending pipes in this manner, however, in that the metal forming the outer curve, or **heel**, of the bend is stretched and made thinner, while that forming the inner part, or **hass**, is compressed and thickened. The gain of metal in the hass is slight compared with the loss of metal at the heel. The heel, consequently, is the weakest part of the pipe. Leaden waste pipes having a diameter greater than two inches should not be bent with sand unless the bends are very easy.

The surplus metal in the hass should be so worked around to the heel of the bend that a uniform thickness is obtained. This is done by the use of a **dummy**, or long rod, loaded on one end with coarse solder, as shown in Fig. 180.

A sudden jerk downwards on the end *A* will throw up the

loaded end *B* with great velocity and will drive the kink *C* in the pipe outwards. This method will thicken the hass,

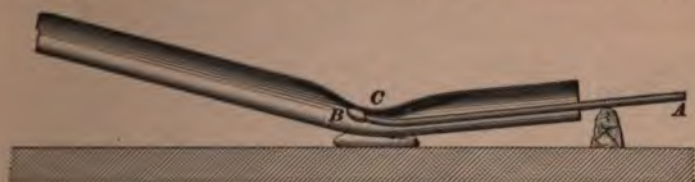


FIG. 180.

but the heel will remain unchanged. A good mechanic will "dress" the surplus material around to the heel and make it the thickest part of the bend.

742. Fig. 181 shows an offset made on a piece of 2-inch lead waste pipe. The bend *A* shows that the sand has not



FIG. 181.

been properly packed, and that it has yielded and been displaced. *B* shows a bend in a well-packed pipe. The heel of *B* will be much thinner than that of *A*.

The wooden sand plugs *C* and *C* are driven into the ends of the pipe, not only to keep in the dry sand, but also to give more leverage in bending the pipe so that the bend can be made nearer the end, which is often desired. By heating the sand immediately before putting it in the pipe, the pipes can be bent more easily. Another method of working lead waste pipes is by means of wooden balls called **bobblins**.

P. II.—4

743. Fig. 182 shows the manner of doing this. After the pipe has been bent in the usual way (over the knee or block) different sizes of bobbins are inserted after having been well greased, beginning with the smallest one and following it up in regular order with the larger ones, as shown in the figure. After the bobbin *b*, whose diameter is the same as that of the pipe, has been inserted, a number of bobbins *a*, *a*, called the **followers**, are inserted which are smaller in diameter than that of the pipe, so that when the largest

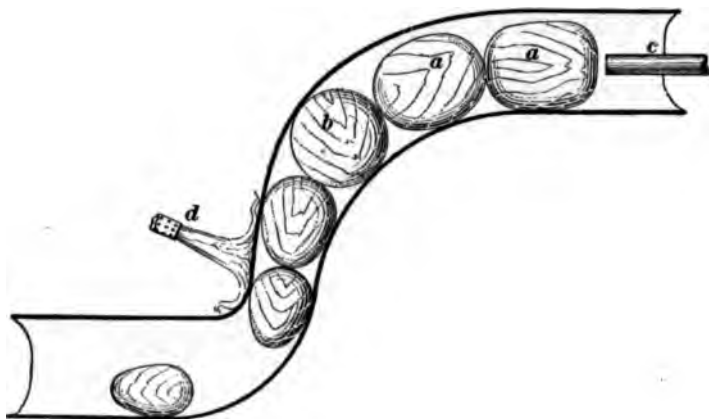


FIG. 182.

bobbin *b* is driven through and out of the pipe by ramming the bobbin with a rod *c*, the followers will drop out easily.

If heat be applied at the throat, as at *d*, it will soften the lead at this point, and thereby cause it to yield more easily to the outward pressure of the bobbins and cause less thinning of the heel, particularly if the heel be kept cool with a wet cloth. The superfluous lead on the sides can be dressed back to the heel. This will somewhat make up for the loss in thickness of this part caused by the pressure of the bobbins as they are driven around the curve.

Sometimes a **close steel spring** is used for bending. This is well greased and placed inside where the bend is required, but the result is a *thin heel*, as when the sand process is used.

744. Thin brass or copper tubing should be *annealed* before bending, as this softens the metal. It is annealed by heating the tube to dull redness and then plunging it into cold water.

To bend the above tubing, first fill that part of it which is to be bent with melted resin or lead, and allow it to cool; then bend it over a curved block to the shape desired. In many cases sand may be used for filling the tube.

Thick brass or copper tubes should also be annealed, after which they may be bent as directed for iron pipe.

In bending **brazed pipe**, the seam should be kept to the inside of the curve so that it may not be stretched and opened.

Nickel-plated brass tubing should not be bent, because the nickel plating will crack and peel off. Tubing which must be bent and which is to be nickel or silver plated, should first be bent and then plated.

745. Wrought-iron pipe should be heated to redness and be bent while hot around a block which is curved to the desired radius. The block should be provided with a groove upon its edge which exactly fits the pipe and prevents it from spreading sideways or kinking. The weld or seam of the pipe should be always kept to the inside of the curve, to prevent splitting the pipe.

PIPE THREADS.

746. The majority of manufacturers of wrought-iron pipe have adopted a standard called the **Briggs standard** system of screw threads for pipes and fittings. A few manufacturers, however, do not conform to it strictly; they use 12 threads per inch instead of the $11\frac{1}{2}$ threads called for in the table.

To make perfect joints with standard fittings, the threads should be cut to a certain distance only from the end of the pipe. This distance is stated in the following table:

TABLE 32.**SYSTEM OF SCREW THREADS FOR WROUGHT-IRON
PIPE, BRIGGS' STANDARD.**

Nominal Internal Diameter in Inches.	Number of Threads per Inch.	Length of Perfect Thread in Inches.
$\frac{1}{8}$	27	.19
$\frac{1}{4}$	18	.29
$\frac{3}{8}$	18	.30
$\frac{1}{2}$	14	.39
$\frac{3}{4}$	14	.40
1	$11\frac{1}{2}$	.51
$1\frac{1}{4}$	$11\frac{1}{2}$	.54
$1\frac{1}{2}$	$11\frac{1}{2}$	.55
2	$11\frac{1}{2}$	.58
$2\frac{1}{2}$	8	.89
3	8	.95
$3\frac{1}{2}$	8	1.00
4	8	1.05
$4\frac{1}{2}$	8	1.10
5	8	1.16
6	8	1.26

All pipe ends are made conical, the taper being $\frac{1}{4}$ inch of diameter per foot of length.

COCKS AND VALVES.

747. **Ground key** or **plug cocks** are constructed as shown in Fig. 183. The plug *B* is turned truly circular, and is also tapered to fit the conical socket *C* which is bored or reamed in the body of the cock. Formerly the plug and socket were fitted to each other by grinding with emery, and they thus became known as *ground key* cocks. The plug is

held in place by means of a screw *E* and the washer *D*. The washer fits over a squared shoulder on the small end of the plug so that they turn together, as otherwise the screw would loosen itself every time the plug was turned. The

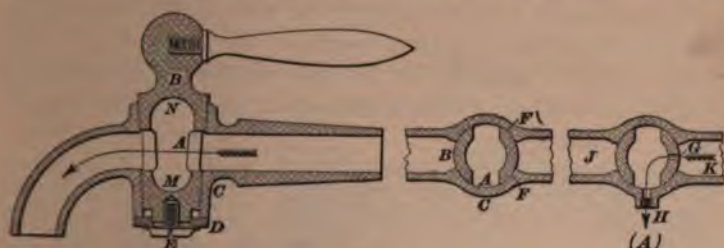


FIG. 183.

waterway through the plug consists of a rectangular slot *A*, and the corresponding openings in the side of the socket should also be rectangular and of the same width. The tightness of the cock will depend upon the perfection of the fit of the plug and socket at the points *F, F'*. If these surfaces are narrow, the cock will soon wear and become leaky.

The plug being of larger diameter at the top edge of the slot *A* than at its lower edge, it follows that there is a difference of area between the top and bottom of the slot; consequently, the pressure of the water within the pipes tends to drive the plug out of the socket. Thus, if the area of the bottom surface of the slot were 1 square inch and that of the top surface of the same were $1\frac{1}{8}$ inches, the difference in area would be one-eighth of one square inch. Supposing a water pressure of 100 pounds per inch, there would be a pressure of 100 pounds upon the bottom of the slot tending to hold the plug in place, and a pressure of $112\frac{1}{2}$ pounds upon the upper end of the slot tending to drive the plug out of the socket. Thus, there would be an unbalanced pressure of $12\frac{1}{2}$ pounds tending to lift the plug, and which must be resisted by the screw *E*. This is a matter of small account in common sizes, but in large cocks it becomes a matter of importance.

Some manufacturers core out the body of the plug, as shown at *M* and *N*, to economize metal. Cocks having these cavities should not be used, if possible, because they greatly obstruct the flow of water.

Plug cocks are either constructed with a *lever handle*, as shown in Fig. 183, or with a handle in the form of a **T**, and known as a *tee handle*, or the top of the plug is shaped to receive a wrench. The lever handle shown in the figure is most commonly used.

748. Plug, or ground key, bibbs are not suitable for water which carries fine sand or grit in suspension. The fine particles of sand will get in between the plug and the socket and cut grooves, thus forming small waterways and causing the cock to leak. Neither are they very suitable for high pressure, if much used, because of the unavoidable wear and tear on the parts whose seats have been ground, which, under a high pressure, will soon leak. They are, however, suitable for low pressure if the water is free from fine grit.

749. Stop and waste cocks are a variety of plug cocks, having a small hole *G* drilled through the side of the plug and another through the side of the socket at *H*, as shown at (*A*), Fig. 183.

The plug of the ordinary ground cock can be given a complete turn, but the plug of the waste cock can only be given a quarter turn. This is accomplished by means of a pin attached to and projecting from the plug, and moves in a groove cut in the top of the socket.

The groove only occupies the space of one-fourth of the circumference, and, as the plug can not travel further than the pin, the cock must be open when the handle is in one position, and closed when in the other.

Care must be taken, when placing stop and waste cocks upon a system, that the draining hole *G* is on the proper side. For instance, in placing a stop and waste cock on a branch from a street main for the purpose of shutting off water from a building, the cock must be so attached that when

shut the opening *G* will be towards the building, so that the pipes therein may be drained at that point. The end *J* of the stop and waste cock shown at (*A*) in Fig. 183 would be connected to the main, and *K* to the house pipes.

750. Three-way cocks are usually constructed as shown in Fig. 184. The key, or plug, *A* has a three-way channel *B* passing through it which can be made to communicate with the openings *C*, *D*, and *E* for the pipe connections. By turning the key, or plug, *A*, communication can be made between *C* and *D* while *E* is shut off; between *D* and *E* while *C* is shut off; between *C* and *E* while *D* is shut off; or they may all be open to one another, as shown in the figure.

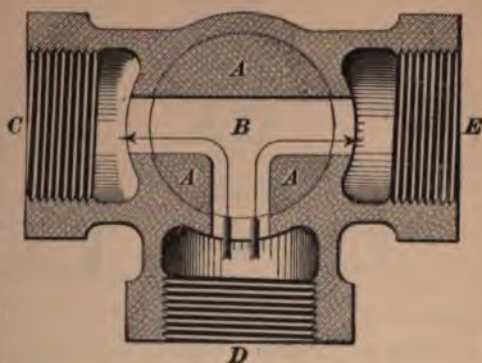


FIG. 184.

751. Swing cocks, as shown in Fig. 185, are a variety of plug cocks. The plug *A* is stationary, and receives the water through the lower end. The socket *B* is provided with a suitable nozzle or discharge *C*, and can be turned on the plug.

The waterway is opened or closed by swinging the nozzle. The form of swing cock shown is called a *basin swing cock*. It is attached to the basin top in such a manner that when the nozzle *C* points towards the center of the basin, the cock will be open, and when tangential to the circumference of the basin the cock will be closed.

752. Regrinding Leaky Plug Cocks.—When a ground plug cock begins to leak it is usually cheaper to re-

place it with a new one. If this can not be done it is customary to *grind it*; that is, to grind down irregularities existing between the external surface of the plug and the internal surface of its socket, so that these surfaces will be in equal contact throughout their area, and thus prevent water from passing between them. The grinding process may be done as follows: Take out the plug of the cock and examine it for the part which does not come in contact with the

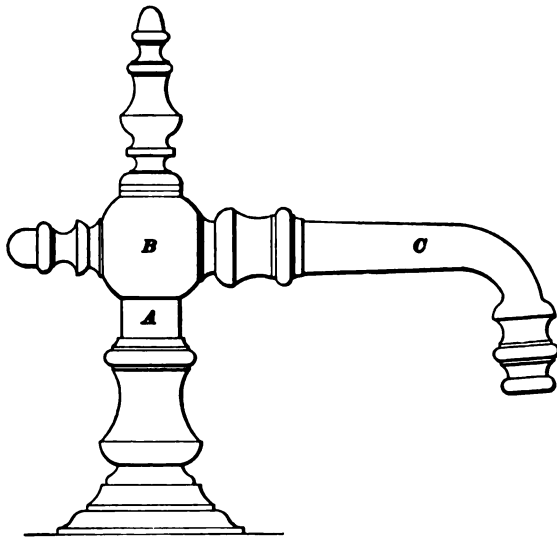


FIG. 188.

socket. This part will be dark in color, and the bearing parts bright and polished. Then sprinkle fine emery or powdered bath brick on the polished parts and insert the plug in its socket. Then, with the hand, partly turn the plug first to the right and then to the left, pulling it out a little and pushing in again at the points where the motion is reversed. The turning motion will grind down the prominent parts of the plug and socket, and the pulling out and pushing in motion, although slight, will cause a uniform film of grinding material between the surfaces. The plug should be occasionally dipped in water and resprinkled with emery.

753. Compression cocks, or bibbs, are constructed as shown in Fig. 186. The water passes through the orifice *R* which is closed by means of the valve disk *B*. This disk is made of some elastic material and is held in a block *C* which is attached by a swivel joint to the end of screwed stem *E*.

If the block *C* is allowed to turn with the screw, the disk *B* will soon be injured and become leaky. The water is pre-

vented from flowing out around the top of stem *E* by placing lamp-wick or other suitable packing in *A*, which is pressed against the stem by screwing down the nut *D* on the bonnet *F*.

Compression cocks are also constructed in other ways, as in Fig. 187. The block *C* is prolonged upwards and con-

stitutes a nut which receives the screw thread of the stem *E*. The stem is provided with a solid collar *r* which bears against the cap *D*, the joint being ground. Thus, the spindle does not rise as the valve opens.

The block *C* is made either square or round. When

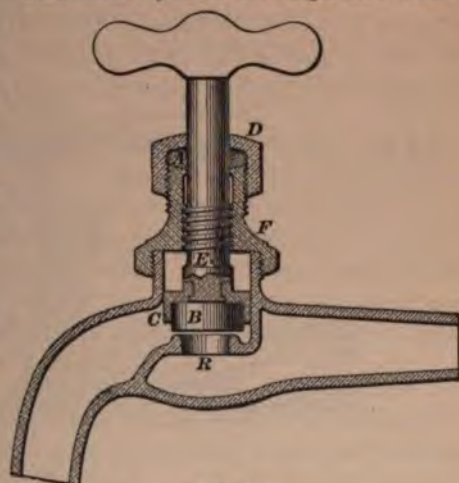


FIG. 186.

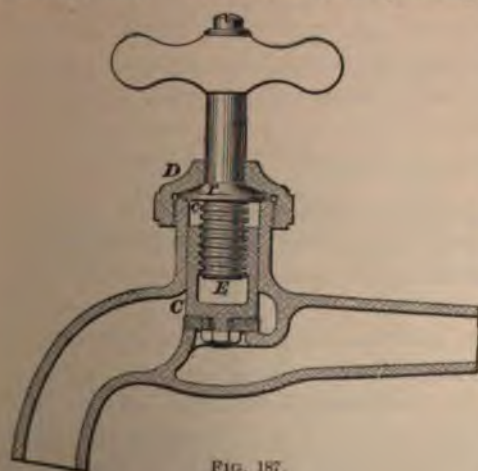


FIG. 187.

round it has two lugs placed diametrically opposite one another, which, upon turning the stem, slide up or down in grooves provided for them in the casting of the cock. This is done to prevent *C* from turning, so as not to wear out the rubber or leather disks too rapidly.

754. Compression cocks are suitable for faucets only, and should not be used as cut-off or controlling valves.

For faucets, compression bibbs have the advantage over plug cocks of closing slowly, and thus avoiding destructive shocks upon the piping. Also, if they become leaky they can be readily supplied with a new valve disk; while, if a plug cock becomes leaky, it must be reground.

755. Self-closing compression cocks differ from the common kind in having a stout coiled spring under the cap to close the valve, instead of the usual screw and handle. The handle is always a lever of some kind, which is so arranged that the valve may be opened by it, but as soon as it is released the spring closes the valve.

The chief objection to the self-closing or *spring* cocks is that they close too suddenly, and cause a shock upon the pipe system. The nature of the shock is similar to that received by a hydraulic ram when the large valve is suddenly closed. Self-closing cocks are only used where water is scarce, so that none may be wasted by careless persons leaving the cocks open when they are not required, or where there is a liability of the cocks being left open and doing damage by overflowing the fixtures.

756. A rapid closing compression cock is shown in Fig. 188. The lower end of the stem *a* is offset and forms a crank *s* of sufficient radius to move the valve *h* to and from its seat. A half turn of the handle will open the valve to its full extent, and the other half turn will close it. The handle may be turned in either direction.

In this form of cock the water pressure is on the back of the soft conical rubber valve *h*, and by pushing the valve against its seat causes less force to be exerted by the person

in closing the valve. The stem is made water-tight by screwing down the nut or cap *c*, which forces down the bushing *b*, and thereby compresses the packing *e* around the

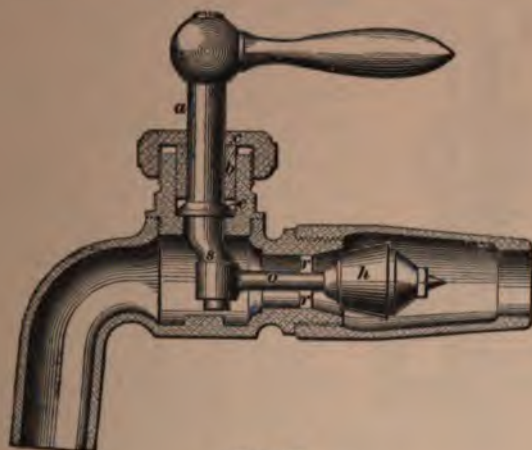


FIG. 188.

stem. The valve is guided to its seat by prongs *r* and *r*, cast on the stem *o*, to which the valve *h* is fastened. These cocks are used chiefly on low-pressure work where the water is free from grit, etc.

757. A common form of **ball-cock** is shown in Fig. 189, which is chiefly used for supplying water to tanks. The

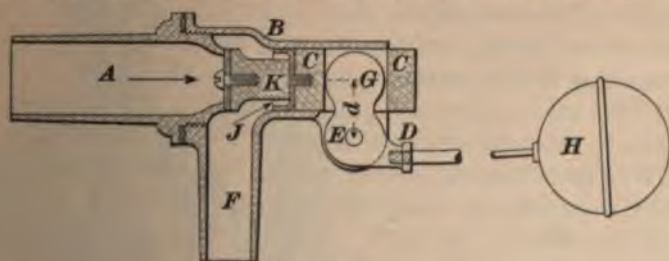


FIG. 189.

body *B* is bored to receive the cylindrical stem *C* to which the valve *K* is attached. The water enters through the pipe

A and escapes through *F*. A cup leather *J* is secured between *C* and *K* which prevents water from passing the guide stem *C*. The ball *H*, which in this cut is drawn considerably

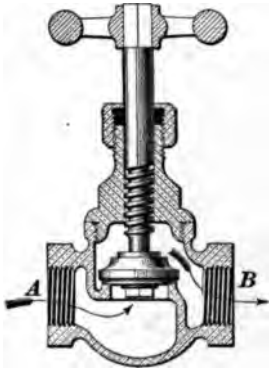


FIG. 190.

smaller than it really is, as compared to the size of the valve, is hollow and its buoyancy in water is utilized to close the valve. It is attached to the lever *D*, the short end of which engages the stem *C* of the valve. As the water rises in the tank to which this valve is attached, the ball floats upwards and gradually pushes the valve to its seat and stops the inflow of water.

When the water in the tank is discharged, *H* drops and thereby opens the valve *K*, which admits water to flow into the tank.

The hollow ball *H*, although carefully made, will sometimes partly fill with water. This causes the ball to sink and allows the water to run and overflow the tank.

758. The ordinary **globe valve** shown in Fig. 190 and **angle valve** shown in Fig. 191 belong to the compression class. The waterway through a globe valve is so contorted that the flow of water is obstructed to a serious degree.

Globe valves should be attached to the pipe system in such a manner that the valve will close against the pressure, as otherwise when the valve is on its seat the water will be liable to work up along the valve stem and leak.

For this reason *A* is the inlet and *B* the outlet of the valve. The same applies to the angle valve. The ordinary globe valve is used on the

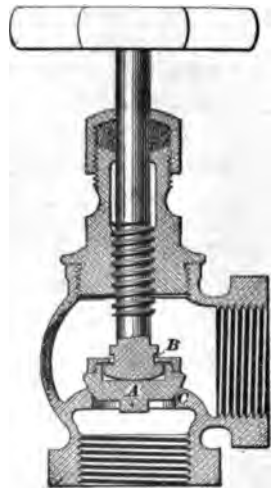


FIG. 191.

straight pipe, while the angle valve is used at the junction of two pipes at right angles.

759. The **gate valve** shown in Fig. 192 is for the same purpose as globe valves. Gate valves furnish a freer passageway for the water. By turning the stem *B* the wedge-shaped disks *A* and *A*₁ are moved across the seats *c* and *c* and the orifice is opened or closed gradually. The disk *A*₁ has cast on its lower side a projection *D* which rests on a corresponding projection *E* cast to the valve body. These are for preventing the disk *A*₁ from moving down too far and thus causing the disks to wedge apart and press tightly against their seats *c* and *c* by turning the stem *B*.

Gate valves are made quick-acting by substituting a lever and sliding stem for the screw stem shown.

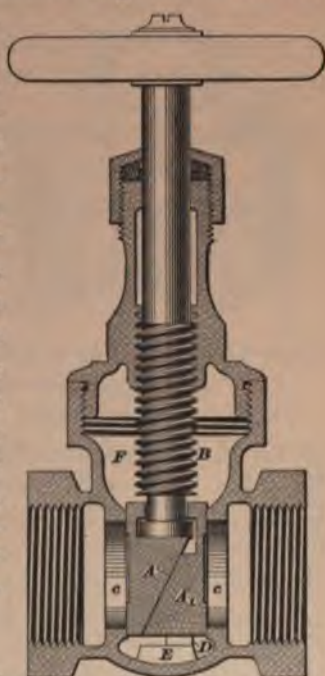


FIG. 192.

760. **Check-valves** are designed to permit the flow of fluid in one direction only and to positively prevent any return flow.

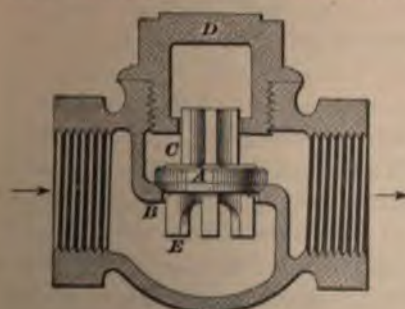


FIG. 193.

The common form of check-valves known as a **globe check** is shown in Fig. 193. The valve *A* is a solid disk of metal having a beveled edge to suit the seat *B*, and is guided by the feathers *C* and *E* as shown. The fluid passes in the direction of the arrows.

761. An improved form of check known as a **swing check** is shown in Fig. 194. The valve disk is attached to an arm which swings on a pin as shown. The passage of fluid through this valve is more direct than in the globe check,

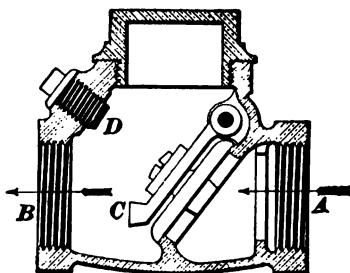


FIG. 194.

and the pressure required to open the valve is much less. The fluid passes through the valve as shown by the arrows, that is, from *A* towards *B*.

In case of a rapid flow of water, the projection *C* on the end of the arm to which the valve is attached strikes against the bottom of the screw *D*, and is thus prevented from going too far.

762. A check-valve specially adapted for drainage purposes, and called a **back-water valve**, is shown in Fig. 195. It is used to prevent water in the street sewers from backing up

in the house drains, as is liable to occur during a heavy rainfall if the sewers are too small or have too little fall.

This valve should never be used on a system of house drainage unless it is

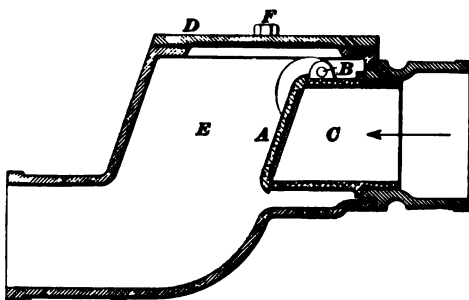


FIG. 195.

absolutely impossible to avoid it, as it is liable to cause a chokeage in the house drains by allowing the liquids to pass and retaining the solids. This is likely to happen if the house drains have little fall towards the valve.

Referring to the figure, it will be seen that the valve *A* swings on a pin *B*; the inlet is indicated by the arrow.

The valve and its seat *C* should be made of brass, so as not to corrode. For facilitating the cleaning out of the valve

a handhole is provided in the body *E*, which is closed by a cover *D*, held in place by bolts *F* on each side of it. To prevent leakage, packing should be placed under the cover.

763. Another form of a back-water valve is shown in Fig. 196. This is used chiefly to drain water from the basement floors, etc., where there is danger of water backing up from the sewers. The valve is composed of a hollow copper float *A*, encircled by a soft rubber ring *B*. A rest, or stop, *E* for the float is attached to the brass valve seat *G* by four arms. These arms also act

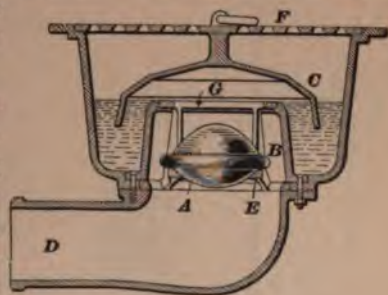


FIG. 196.

to its seat when the sewage water rises in the drain pipe *D*, and buoys up the valve. When the water falls in *D* the float will fall from its seat and descend with the receding water until it reaches its stop, as shown, when it will be again open for surface water. A bell-shaped casting *C*, suspended from the perforated cover *F*, dips into water and forms a seal to prevent drain air from entering the building. This form of check-valve is commonly called a **back-water trap**.

764. Safety valves are designed to open when the internal pressure becomes too great; they permit the fluid to escape until the excess of pressure is relieved, after which they close again.

One form of these valves, called a **lever safety valve**, is shown in Fig. 197, in which the valve *C* is held down on its seat against the upward pressure acting on the bottom of it by a lever *L* and weight *W*. Instead of holding down the valve in this manner, it is held down sometimes by means of a weight placed directly on the valve stem *D*, and is then known as a **dead-weight safety valve**, or by means of a

strong spring acting on the valve stem, and is then known as a **spring** or **pop safety valve**.

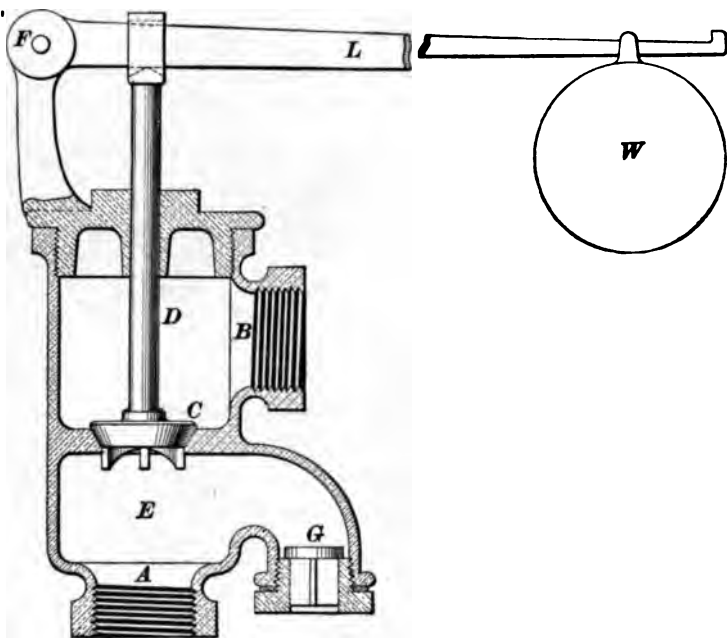


FIG. 197.

765. Vacuum valves are similar to safety valves, except that they operate in the reverse way, the internal pressure acting upon the top of the valve and the external or atmospheric pressure acting on the under side. Thus, if a vacuum is being formed within a boiler so that there is danger of its collapsing from the external pressure of the atmosphere, the valve will open and will allow enough air to enter to destroy the vacuum. Safety valves and vacuum valves for plumbers' use are commonly combined in one structure. Such an arrangement as this is shown by Fig. 197, in which *G* is the vacuum valve.

766. The action of the lever safety valve and the vacuum valve is as follows:

Suppose the nozzle A to be attached to a vessel under pressure so that communication is made between the vessel and the chamber E . Then the fluid contained in E being under pressure, tends to raise the valve C off its seat and force the valve G downwards to its seat. When the pressure of the fluid per square inch in E multiplied by the area of the bottom of the valve C is greater than the weight of the valve C and stem D plus the force due to the weight W and lever L acting on the valve seat, the valve C will rise and the fluid will pass out of B into the atmosphere. After the pressure of the fluid in E and in the vessel has fallen a pound or so below that required to raise the valve C off its seat, the valve C will again close.

Should the pressure in the vessel to which the safety valve is attached become less than that of the atmosphere, a partial vacuum would then exist in the chamber E , and the atmospheric pressure would force upwards the valve G and thereby open it and admit air, which will destroy the vacuum and prevent the vessel from collapsing.

The pressure at which a lever safety valve will blow off depends upon the weight of W and upon the distance it is placed on the lever L from the fulcrum F . The nearer it is placed to the fulcrum F , the less will be the blow-off pressure, and the further it is placed from it the higher will the pressure rise before the valve will blow off.

The lever of a lever safety valve should be raised by the hand periodically, as the valve is liable to stick to its seat.

767. Pressure-reducing valves, shown in Fig. 198, are used for decreasing fluid pressure. In this Course, however, we shall treat only of that form used for liquid pressure. They are chiefly used in cities where the street water pressure is too great for the plumbing systems in the buildings to safely withstand. Their duty is to reduce the pressure within the building to a safe and suitable point.

Pressure-reducing valves are generally attached to the pipes which supply the buildings from the street mains

whose pressures are to be reduced, and are usually located in the cellars of the buildings.

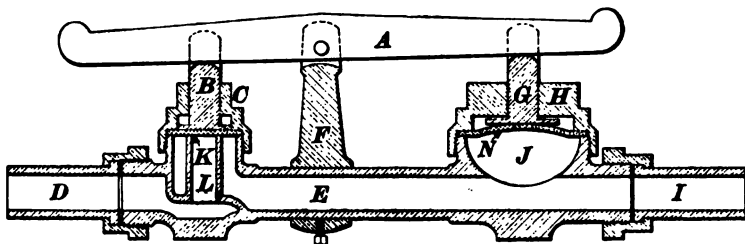


FIG. 198.

768. In the form of regulator shown in Fig. 198, the water having high pressure enters at *D* and passes up the tube *L*. The orifice of this tube is closed by a flexible disk or diaphragm *K* which is held down by a plunger *B*. When the pressure on top of *B* is diminished, the water lifts *K* and escapes over into the pipe *E*. The water in *E* also fills the chamber *J* which is closed by the flexible diaphragm *N*. The plunger *G* rests upon the top of the diaphragm *N*, and its motion is transmitted by means of the lever *A* to the plunger *B*. Owing to the large area of *N* and smaller area of *K*, a lower pressure per square inch is required in *E* than in *D* to cause an equal upward force upon the plungers *B* and *G*. If the fulcrum *F* is equidistant between the plungers *B* and *G*, and if the tension of the rubber diaphragms, and the upward pressure upon the annular ring of the diaphragm *K* around the orifice of *L* be omitted, the areas of the orifice of *L* and of the diaphragm *N* will be inversely proportional to the pressures per square inch in *E* and *D*, respectively; that is, the area of *L* when multiplied by the pressure per square inch in *D* should equal the area of *N* when multiplied by the pressure per square inch in *E*. The pressure in *E* can be adjusted, however, by shifting the fulcrum *F* of the lever *A* along upon the tube *E*, *F* being provided with a suitable clamp for that purpose. Thus, if *F* be set nearer to *B*, a lower pressure in *E*, and, therefore,

under N will balance the pressure under K , and *vice versa*.

Whenever the pressure falls in E the water from D will pass by K until the pressure in E is restored. Should the pressure in D be removed by shutting off the service water or otherwise, the diaphragm K will be closed by N , its area being much greater than that of K , and no water will be allowed to escape back through the apparatus. It thus acts as a check-valve.

769. Fig. 199 shows a pressure-reducing valve a connected to a service pipe $b b$ in the basement of a building,

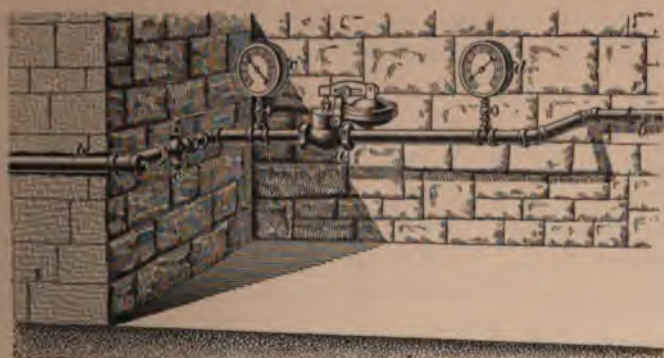


FIG. 199.

and near the point where the service pipe enters the building. The pressure gauge shown at c is employed to indicate the pressure in the service pipe on the street side of the reducing valve, and d indicates the pressure of the water in the house pipes.

These gauges are exceedingly convenient, and we recommend their use along with any form of a reducing valve.

The gauge d will indicate whether the valve a is tight or leaking. If it leaks, even a trifle, the gauge d will soon indicate a pressure nearly or quite equal to that indicated by c , when no water is being drawn from the faucets in the

building, and thereby gives a fair notice that the pressure-reducing valve requires repair. The stop-cock shown at *c* in Fig. 199 is of the stop and waste form, and is used to shut the water off the entire building.

TABLE 33.

MELTING POINTS OF METALS.

770. The melting points of the metals used in plumbing are given in the following table:

Metal.	Temperature in Degrees F.	Metal.	Temperature in Degrees F.
Cast Iron.....	2,192	Zinc	680
Copper	2,100	Lead	626
Silver	1,800	Bismuth.....	505
Brass (common).	1,900	Tin	446
Antimony	1,000	Sulphur.....	228

The fusing point varies greatly according to the purity of the metal, and the fusing points of alloys vary according to the composition. The temperatures given above are fair averages.

SOLDER.

771. Solder is an alloy of two or more metals, which, when melted, will adhere strongly to the cleaned surfaces of other metals which are less fusible.

Solders are classified as **hard** or **soft**, according to their relative fusibility. Any desired fusing point may be obtained by varying the proportions and kind of ingredients. The following table shows the composition and fusing points of the various solders in common use;

TABLE 34.

SOLDERS.

Variety.	Hard.			Soft.			Fusing Point.
	Zinc.	Copper.	Silver	Tin.	Lead.	Bismuth.	
Spelter, hardest...	1	2	....	....	....	....	700°
Spelter, hard.....	2	3	....	....	....	....	....
Spelter, soft.....	1	1	....	....	....	....	550°
Spelter, fine.....	2	2	$\frac{1}{4}$	....	....	....	....
Silver, hard.....	....	1	4	....	....	....	....
Silver, medium....	....	1	3	....	....	....	....
Silver, soft.....	....	1	2	....	....	....	....
Plumbers', coarse.	....	....	....	1	3	....	480°
Plumbers', ordinary.....	....	....	....	1	2	....	441°
Plumbers', fine....	....	....	....	2	3	....	400°
Tinners'.....	....	....	....	1	1	....	370°
For tin pipe.....	....	....	....	3	2	....	330°
For tin pipe.....	....	....	....	4	4	1	....

772. Making Soft Solder.—To make good solder it is necessary to secure pure materials. The lead and tin of commerce vary considerably in purity.

After deciding upon the proportions of lead and tin which are required to make the desired variety of solder, the lead should be melted first, care being taken to avoid overheating the metal. The melted metal should be stirred thoroughly, and the dross which floats on the surface removed. The tin should then be added, and as soon as it is melted the metal should be stirred so as to secure the thorough mixture of the lead and tin. While stirring, a small quantity of black resin should be added. When the metal becomes hot enough to ignite a piece of newspaper, it should

be skimmed and then poured into molds. Care should be taken that the molds are clean and dry.

The two metals will separate if the melted solder is allowed to stand without stirring, because of the difference in specific gravity of the lead and tin, their weights being in the proportion of about 11 to 7. Therefore, thorough stirring is indispensable.

Soft solder is quickly spoiled by overheating. Both metals oxidize rapidly at low red heat, and the tin oxidizes faster than the lead. A thick yellow crust forms on the surface of the molten metal, which excludes the air and thus retards the oxidization. If this crust be left undisturbed until the metal cools to the proper working temperature, which is not over 600°, and then be removed, the solder may be restored to proper quality by adding a little tin. The molten metal should not be stirred while any oxide remains upon its surface.

Soft solder becomes impure and useless by the gradual accumulation of oxides, or iron and brass filings, and also by contamination with zinc.

773. A common method of **purifying soft solder** is as follows: The metal is heated to about 800°, which is a very dull red heat, just visible in the dark, but not visible in daylight. A quantity of sulphur is thrown upon the metal as soon as it is melted, and the metal is then well stirred in order to bring all parts of it into contact with the sulphur. The sulphur combines with the zinc and brings it to the surface as dross. The oxides will also come to the surface; sometimes they will cling to the sides of the pot. The metal is then thoroughly skimmed, taking off the crust whole, if possible, and allowed to cool to low working heat, about 480°, after which a little tallow is stirred into it. This will remove the last of the sulphur and the metal will appear very clean. It will probably require the addition of a little tin to restore the proper quality.

Sometimes a batch of soft solder will work well for about a dozen heats and then become unworkable. This is usually

due to impurities in the tin, it being contaminated with antimony or bismuth.

As a proof that the tin will separate from the lead when the solder is in a semi-molten or "half-set" state, dig a hole in the nearly set solder in the pot, and the tin will filter down and settle in a little pool at the bottom of the hole, leaving a chalky-looking and porous metal above.

774. Testing the Quality of Soft Solder.—Having the melted solder at a temperature of about 600° (which will scorch paper, but will not ignite it), pour a little of it upon a smooth stone, preferably a slab of pavement, which is perfectly dry, clean, and level, and form a cake as large as a dollar, and about one-eighth of an inch thick. Good solder will show a number of clear spots, from four to six to the square inch, upon the top surface of the cake. If the cake turns white and chalky, the solder is probably too coarse; that is, the percentage of lead is too great. If it cools with a bright top surface, with, perhaps, a little gray or chalky center, the percentage of tin is too great. This test is employed by expert plumbers, and they, by long experience, can tell at a glance whether the solder is too fine or too coarse, or whether pure or impure.

The *most certain way* for the inexperienced man to test the quality of solder is to prepare a lead pipe and proceed to make a sample wiped joint upon a small piece of old lead pipe, after having first tested it to the best of his ability by the above method. If the solder does not "work" to suit him, he can easily adjust it before he proceeds to wipe the joints intended for use. By using this precaution the young plumber will save himself much labor and worry, and his employer much expense. He will also obtain better results than he would by trying to adjust the solder while operating on the real work. If the solder is good, it will cling to the pipe and remain plastic until too cool to work. If the proportion of tin is too great, it will set or harden too quickly, and the metal will appear bright, but ragged. Beads of tin will probably even drop from the under side of the joint.

If the proportion of lead is too great, it will require a long time to "get up the heat," and when the joint is finished the metal will appear chalky and porous.

If the alloy is "just right" and if it is "worked" properly and not too slow, the joint when finished should be bright, shining, and smooth.

FLUXES.

775. Fluxes are used to aid the fusion of solder and to clean the surface of the metals to be joined, and thus promote the adhesion of the melted solder.

The following table gives some of the most common fluxes, and the metals they are chiefly used upon:

TABLE 35.

Flux.	Metals to be Joined.
Resin	Lead, tin, copper, brass, and tinned metals (used with the copper bit or blowpipe).
Tallow (without salt) ...	Lead, tin, or tinned metals (used with the blowpipe or wiping process).
Sal-ammoniac	Copper, brass, and iron (used with the copper bit or blowpipe).
Muriatic acid, or hydrochloric acid	Dirty zinc (used with copper bit).
Chloride of zinc	Clean zinc, copper, brass, tin, and tinned metals (used with copper bit or blowpipe).
Resin and sweet oil	Lead and tin tubes (used with copper bit or blowpipe).
Borax	Iron, steel, copper, and brass (used with blowpipe).

776. Chloride of zinc is prepared by mixing *muriatic* (*hydrochloric*) acid with *zinc* which is in the form of grains, chips, or strips. The acid and zinc rapidly combine, and during the process a quantity of gas is disengaged, which causes the liquid to boil and emit copious fumes which are very corrosive. Considerable heat is also generated. The acid may be diluted with water to reduce the strength of the solution when desired. When the liquid stops boiling or giving off bubbles of gas, the acid is **saturated**; that is, it has dissolved all of the zinc that it is capable of holding in solution.

Chemically pure muriatic acid is clear as water, while the commercial is yellow. This is on account of the impurities it contains, such as iron, arsenic, or organic matter. The commercial is good enough to use in making the chloride of zinc flux.

TINNING AND SOILING.

777. The operation of tinning consists in spreading a thin layer of solder (or sometimes of pure tin) upon the surfaces of other metals and causing it to adhere and make a firm metallic union therewith. The object of the tinning is to so prepare the surfaces of the metals that they will readily unite with the melted solder which is applied to them in the process of making joints.

Soldering bits must also be tinned. This is done in the following manner: While the bit is hot the scale and oxide should be filed off the parts to be tinned, which thus exposes the clean copper. Then, before the copper has time to oxidize rub on the parts so filed a stick of solder which has been previously dipped in flux. The tinning operation is best performed at a moderate heat; if the bit is red hot it will oxidize the instant that the file leaves it, and no tinning can be done.

A quick and convenient way of tinning a bit is to rub it while hot upon a block of sal-ammoniac having a few drops of solder spattered over its surface. The sal-ammoniac

reduces the oxide, and the clean copper seizes the solder instantly upon coming in contact with it.

When a bit is overheated, the coating of solder, or the tinning as it is called, is reduced to a yellow powder and is destroyed. The tinning must be restored before it can be used.

Resin is recommended as a flux for tinning soldering bits which are to be used for soldering lead, and for tinning all brass and copper work upon which soft solder joints are to be wiped. Chloride of lime or sal-ammoniac is, however, quite suitable for tinning soldering bits which are to be used for soldering sheet copper, sheet tin (not block tin), iron, etc.

778. Tinning of Sheets, Etc.—A flat surface, such as the edge of a sheet, may be tinned by first spreading a proper flux over the surface to be tinned; then, by using a hot bit, melt off a small lump of solder, allowing it to fall upon the flux at the desired spot. Now apply the bit to the solder, and as soon as the metal beneath it becomes hot enough the solder will flow and spread out over the surface. If the sheet be placed on an incline and the work is begun at the top, the superfluous solder will follow the hot bit downwards. This will help to keep the tinning of uniform thickness and free from irregularities. Small lumps or ridges in the coating of solder thus applied will interfere with the proper closing of locked seams, and care must always be taken to remove them.

Articles composed of brass or copper, such as *cocks*, *nipples*, etc., may be tinned by first filing the surface to thoroughly remove the coating or oxides so as to expose the clean metal, then coating it with a flux (usually resin). Molten solder is then applied to the brass with a bit so as to entirely cover the filed surface. The superfluous solder, if any, is shaken off before it sets. It is bad practice to dip the brass into a pot of molten solder which is to be used for wiping purposes, because some of the zinc (of which the brass is partly composed) will melt out and alloy with the solder, and will spoil it.

Articles which are composed wholly of copper may be dipped in the solder pot without injury to the solder, provided that they are perfectly clean and free from filings, etc.

Iron articles may be tinned by thoroughly cleaning the surfaces and treating them with chloride of zinc or sal-ammoniac before applying the solder.

Great care must be taken, when filing brass or other metals preparatory to tinning them, that the filings do not fall on the bench or on the floor at such places that solder falling from wiped joints may pick them up.

As a precaution, the plumber should see that the filing is not done near the bench where the wiping is to be done.

779. Soiling.—The object of soiling is to prevent the solder from flowing upon those surfaces which are protected by it, or from adhering to them. It thus enables the workman to keep the solder within proper limits and to produce clean, nice-looking work, free from all unsightly splashes or irregularities.

In preparing for wiped joints, the soil should be applied over a space of two to three inches on each side of the joint beyond the surfaces which are cleaned to receive the solder.

For work that is to be done with the copper bit or with the blowpipe, a width of soiling of one-half to one inch is usually enough.

The solder should not be applied until the soiling is dry. In fair weather it will dry quickly, but if it dries too slowly the drying may be hastened by applying a moderate heat. Strong heat will spoil it.

METHODS OF JOINING METALS.

780. The principal methods used by plumbers for joining metals are **soldering**, commonly known as soft soldering, **brazing**, and **burning**.

Soldering is divided into three distinct classes.

1st. Soldering with the bit, or soldering iron known as **copper bit work**.

2d. By the application of molten solder to the parts to be joined, known as **wiping**.

3d. By the use of a blowpipe, in which solder is melted by the blowpipe flame and allowed to flow into the joint, known as **blowpipe work**.

Melted solder exhibits a strong tendency to adhere to the surface of the ordinary metals, and to unite solidly with them while cooling. The least film of oxide or of grease or dirt upon the surface of the metal will usually prevent the adhesion. Therefore, the surfaces must be thoroughly cleaned, or they must be coated with some substance which will reduce the oxides to the metallic state, or which will destroy the grease and deposit a thin film of zinc upon the surfaces to be soldered.

A solder containing equal parts of lead and tin, commonly called **half and half**, is suitable for joining lead, copper, brass, zinc, and iron to metals of the same kind, or for joining any of them to any other named.

Block tin, however, requires a more fusible solder, the proportions of which are shown in Table 34, Art. 771. Care must be taken that the temperature of the bit is not high enough to melt the tin. Resin is the proper flux.

Copper, brass, or iron not galvanized may be prepared to receive solder by cleaning the surfaces and applying chloride of zinc. A stronger joint is insured by tinning the metal, as explained in Art. 777, before soldering, and in that case resin would be the proper flux.

Galvanized iron or sheet zinc should be cleaned with muriatic acid before applying the solder. All metals except lead and tin should be tinned previous to wiping. Lead and tin only need to be shaved clean.

The temperature of the metals must be raised, at the point where the solder is applied, to the fusing point of the solder. In soldering metals whose temperature of fusion is slightly greater than that of the solder applied, such as lead or tin, care is necessary to avoid melting them and thus making a hole where it is not wanted.

Solder flows best at high temperatures, provided that the temperature is not so high as to oxidize it. Solder will flow into a joint until it is chilled; therefore, it will flow farthest when it possesses a large excess of heat above that which is necessary to maintain it in the fluid condition. Soldering should not be done with bits which are barely hot enough to melt the solder, because the solder will unite only at the edges of the metal and will not flow or "sweat" into the joint properly.

The bits used for soldering must be of sufficient weight to contain the heat which is necessary to heat the metal and fuse the solder during a reasonable length of time. If they are too light the soldering is apt to be very uneven in quality, and the bits will require such frequent reheating that they will be troublesome. If they are too heavy, then the work of handling them will be too laborious.

The metal to be soldered may be heated by mere contact with the hot bit, but the heating may be done more effectively and much quicker by melting a little solder at the point of the bit. This body of solder increases the area of the contact and conducts heat from the bit to the metal with great rapidity.

The heat necessary for making wiped joints is supplied wholly by the molten solder; therefore, it is essential that the solder should possess a considerable surplus of heat. The temperature is limited, however, by the tendency of the solder to oxidize.

In working with the blowpipe, the necessary heat is applied directly to the metal by the flame. The flame must be handled in a manner which will avoid overheating or oxidizing either the metal or the solder.

781. The work done with the copper bit is of four kinds, which are called,

- 1st. Flat or locked seams ;*
- 2d. Cup joints ;*
- 3d. Bead, or floated seams ;*
- 4th. Overcast joints.*

The flat, or "*lap*," *seam* is used only for joining thin sheets of tin (tinned iron), copper, or zinc. It is not suitable for work requiring any considerable strength. The **lock seam** is made by folding the edges of the sheets and interlocking them as shown at *A*, Fig. 200. All of those surfaces which come into contact, in the inside of the seam, must be thoroughly cleaned before the folding is done. When the metal is tinned upon one side, as in the case of *tinned copper*, the folds are turned so that the tinned surfaces will face each other. If the copper is without tinning, it is advisable, although not

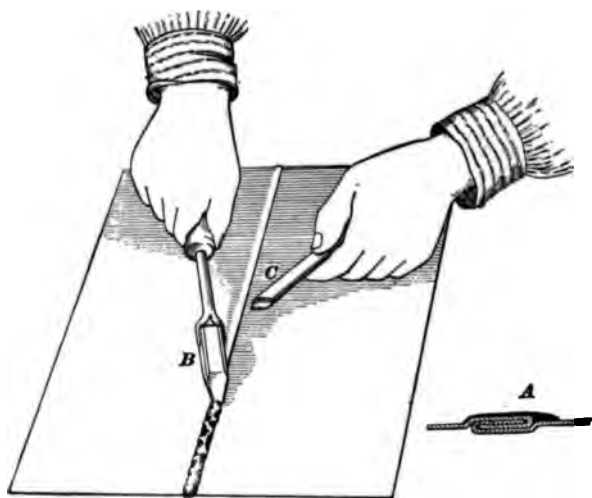


FIG. 200.

strictly necessary, to tin the surfaces that will come inside of the seam. The solder will flow easier, and there is more certainty of securing a perfect joint throughout the entire seam than without it. After the sheets have been secured in place so that they can not shift or get out of place while soldering, the seam should be closed with the mallet. A proper flux is then applied, and the hot soldering bit is held against the head of the seam as shown in Fig. 200. The point rests upon the seam, and a little solder is melted from the bar *C*, and flowed to the point of the bit. As soon as the

metal becomes hot enough, the solder will *sweat* into the interior of the seam, and the manner of its disappearance or soaking into the seam will indicate to the experienced eye whether or not the work is being properly performed.

When the temperature of the bit falls near to the fusing point of the solder, or is cold, the solder will not flow into the interior of the seam, but will adhere at the edges only. The result is called *skin* soldering, and should always be avoided. Cold bits should not be worked back and forth over the seam with the expectation of working the solder in; the action will only aggravate the "skin work." If the interior is poorly soldered, nothing but a hot bit will cause the solder to flow and spread properly.

Lap, or lock, seams should not be soldered in a vertical position with the bit, but should be laid horizontally, because there is great difficulty in securing a solid joint; it is very likely to be skinned over, in spite of the care that may be bestowed upon it.

782. Flat seams, in sheet lead, should be *butted*, as in Fig. 201. The edges of the sheets *A*, *A* are straightened by rasping or planing, and are afterwards beveled with the shave hook, so that when the sheets are laid as shown, there will be a V groove between



FIG. 201.

them. The angle of this groove should be sufficient to permit the edge of the hatchet bit to penetrate nearly to the bottom of it. Soil is then applied in a strip about three-fourths of an inch wide along both edges, on both top and bottom sides of the sheets, as shown at *B*, *B*, and this should be dried before proceeding to solder. The joint should be laid upon a board; if it rests upon a metal surface the heat will be conducted away or *robbed* from the edges to be joined, so rapidly that good soldering can not be done.

If the work must be done on a metal surface, lay two or three thicknesses of thick paper under the joint.

After the lead sheets are securely fastened in position, the edges of the joint may be *tacked* together with a drop of solder at intervals of three to six inches. The hatchet bit *A*, shown in Fig. 202, must be well tinned upon the sides,

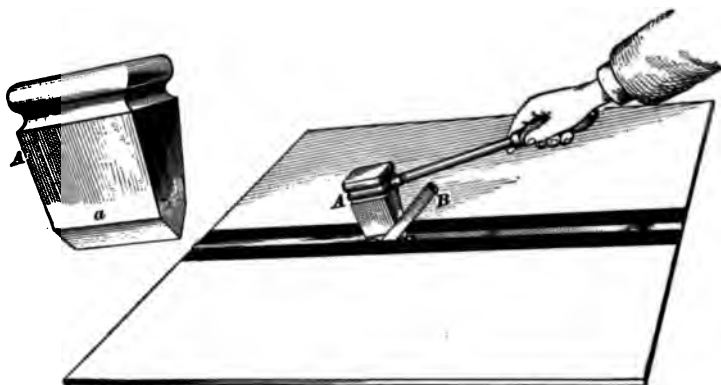


FIG. 202.

as at *a*. Solder is fed to the seam by rubbing the end of a bar *B* against the tinned side of the bit. The groove is filled with solder during the first operation, and the *floating*, or smoothing and finishing, is performed afterwards as a second operation.

As there is only a comparatively small margin of difference in the melting points of solder and lead, great care must be taken to regulate the temperature of the bit and avoid burning holes in the lead. If the bit is too hot, the work must be touched very lightly and the solder must be fed very rapidly, but as it reaches the lower limit of heat it may be allowed to bear its weight upon the seam and to proceed slowly. The seam should be filled uniformly with solder throughout its length.

Then, while it is still warm, proceed to *float* it. Sprinkle it with resin, then take the hatchet bit, sink it into the seam and draw it along slowly and steadily at a speed varying with the heat of the bit. This floating operation levels off

the solder and should leave a flat, smooth, and shining beaded seam, as at *C* in Fig. 201.

783. A **beaded joint** on lead pipe may be made as shown in Fig. 203. The ends are beveled in a similar manner, and are butted solidly together, care being taken that no crevice exists between the ends through which solder can run into the interior of the pipe. The parts are then tacked in position, and the groove is filled with solder. The



FIG. 203.

floating is done while the pipe is slowly turned. This joint is much superior to the cup joint shown in Fig. 204. If the joint is not carefully fitted, or if it is burned, the solder is liable to flow inside, as shown at *a*, and will soon be the cause of a chokage in the pipe, should it be used as a waste pipe.

784. The **cup joint**, shown in Fig. 204, is a cheap form of joint for lead pipes. It is suitable only for light pipe which is subjected to little or no pressure, and is not to be recommended on good work. It is generally recognized in the plumbing trade as one of the many ways of detecting a plumber's status.

The best plumbers in this country seldom, if ever, risk a cup joint on a good job.

The cup joint is chiefly resorted to by tinsmiths in country villages, and others who can not wipe a good joint.

One end of the pipe is cupped with the turn pin, as shown at *A*, and the other end *B* is shaved and beveled to fit *A*. The fitting must be carefully done, so that no crevice exists

between the ends by which solder may run through to the interior of the pipe. The beveled end must be cleaned to at least $\frac{1}{4}$ inch above the edge of the cup *A*, and soil should be applied to about $\frac{1}{2}$ inch above the cleaned surface. Sprinkle powdered resin in the cup, and proceed to fill the cup with solder, being careful to avoid burning either the side of the pipe or the edge of the cup. Fill the cup a little

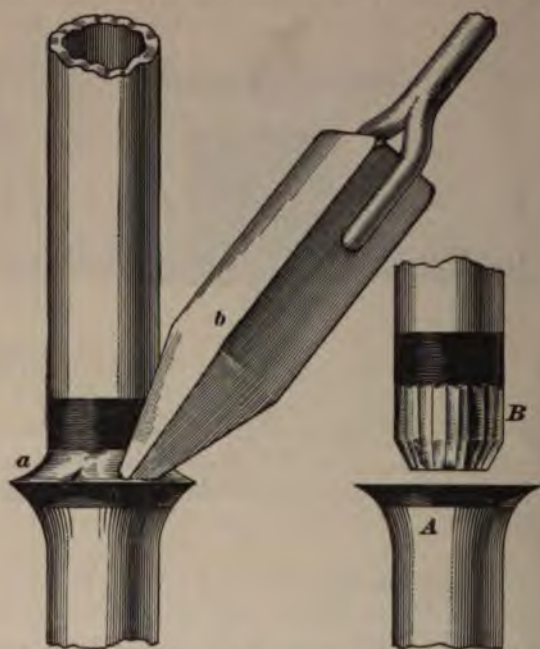


FIG. 204.

more than half full of solder, sprinkle a little more resin upon it, and then float it by means of a long-pointed bit *b*, as shown. Sink the point deep into the solder and move it slowly around the cup. The solder should be left smooth, bright, and curved, as shown at *a*.

Fig. 205 shows a bad job. The fit between the ends was so bad that solder ran through the joint and formed beads and sharp-pointed drops, sometimes called "*sogers*," upon the inside of the pipe. These will catch lint, hair, etc., and

thus choke the pipe. By bearing against the side of the pipe with the hot bit, a hole has been burned through at *A* and nearly through at *B*, while the edge of the cup has been burned at *C*.

785. Solder Nipple

Joints.—Connections between pipes which are united by solder to other pipes which are joined by screw threads may be made by means of a **solder nipple**, as shown in Fig. 206. The nipple *C* is made of brass and is joined to the lead pipe *A* by a wiped joint *D*, as shown; the opposite end is provided with an external screw, which is adapted to connect with a threaded fitting, as at *B*. A square or hexagonal shoulder *E* is cast on the nipple to facilitate screwing

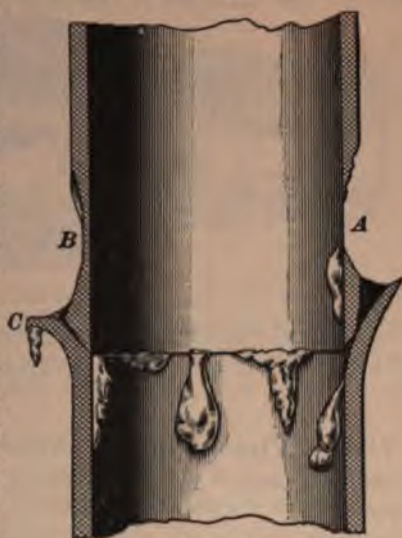


FIG. 205.

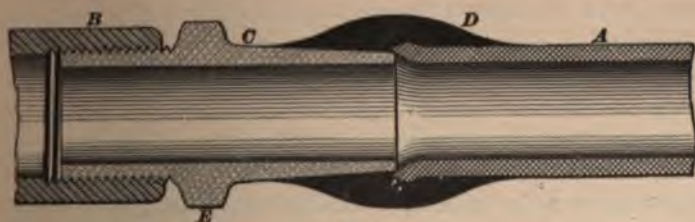


FIG. 206.

up. A lead pipe should never be wiped onto an iron pipe. A brass or copper solder nipple should always be employed.

786. The **overcast joint** shown in Fig. 207 is commonly used to connect a lead pipe to a very short and small nipple or half coupling *E*, as shown. The lead pipe *C* is

beveled at the end, and is closely fitted to the brass nipple *E*. The solder is first applied near *A*, and is floated by moving the bit from *A* towards *B*, thereby overcasting the

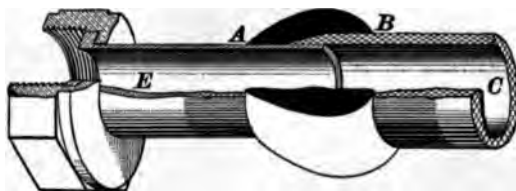


FIG. 207.

metal upon the lead pipe. The outer surface of the solder will be more or less rough, according to the skill with which the bit is handled. Care must be taken to thoroughly tin the metals to be joined before overcasting.

787. Wiped Joints.—This process of making joints, called **wiping**, is used for joining lead to lead or to brass or copper, etc.

In making these joints, the metals to be joined should be heated to a temperature nearly equal to that of the fusing point of the solder applied. Care should be taken that they are not heated to their own melting point.

The parts are heated by pouring over them a quantity of molten solder, the proper temperature of which varies with different classes of work. The solder usually employed for wiping is composed of two parts of lead to one part of tin and melts at a temperature of about 441° . When used for wiping lead it should be heated to, but not over, 626° , which is the fusion point of lead. This allows a margin of about 185° which is available for heating the metals to be joined. The solder pot should be kept at that temperature as nearly as possible.

In wiping joints on *lead pipe*, the parts to be joined are *scribed, soiled, shaved, beveled, and cupped*, as shown in Fig. 208. The parts *A* and *B* must be carefully fitted together so that solder can not run through to the inside of the pipe. To prevent the shaved portions from tarnishing before wip-

ing, they should be rubbed with mutton tallow, which also forms the flux.

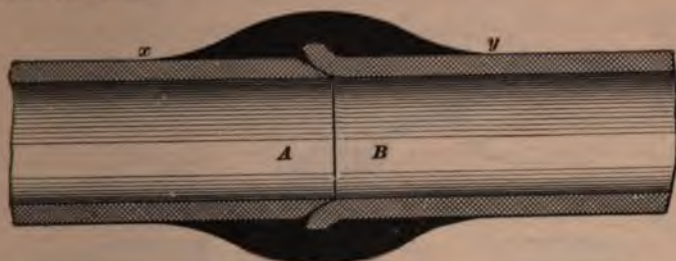


FIG. 208.

The length of the joint, that is, the distance between x and y , should be about equal to that given in the following table :

TABLE 36.

LENGTH OF WIPE JOINTS FOR LEAD PIPE.

Diameter of Pipe, Inches.	Length of Joint, Inches.	Diameter of Pipe, Inches.	Length of Joint, Inches.	Diameter of Pipe, Inches.	Length of Joint, Inches.
$\frac{1}{2}$	$2\frac{1}{8}$	$1\frac{1}{4}$ water	3	2 waste	$2\frac{1}{4}$
$\frac{5}{8}$	$2\frac{1}{4}$	$1\frac{1}{4}$ waste	2	$2\frac{1}{2}$ waste	$2\frac{1}{2}$
$\frac{3}{4}$	$2\frac{1}{2}$	$1\frac{1}{2}$ waste	$3\frac{1}{4}$	3 waste	$2\frac{1}{2}$
1	$2\frac{3}{4}$	$1\frac{1}{2}$ waste	$2\frac{1}{4}$	4 waste	3

For larger than 4-inch, the joint may be from three to four inches long if it be made in a horizontal position. Joints which are made shorter than given in the above table are liable to be weak, and those made longer involve a waste of solder.

The parts should be carefully secured in place so that they can not shift while the joint is being wiped. In Fig. 209 they are held steady by the use of two bricks A, A . Of

course, special clamps may be made or purchased for the purpose; but in ordinary work, bricks are generally used. A



FIG. 209.

space of at least four inches must be had below and on both sides of the joint, to provide room for the movement of the hands and the cloth.

788. To make a joint in an ordinary $\frac{3}{4}$ -inch lead water-pipe, about 10 pounds of solder should be melted in the pot and heated to the proper temperature. Warm the wiping cloth until it becomes pliable, and hold it in the left hand, steadying it with the thumb, as shown in Fig. 209. The cloth should form a dish, or hollow, to receive and retain the solder which falls from the joint, in order to heat the under side of it. Joints wiped in this manner are generally classed as **underhand wiped joints**. The parts which are to receive solder having been rubbed with mutton tallow, and securely fastened, the solder in the pot is thoroughly stirred and taken up with a ladle. The solder is then slowly poured over the joint, as shown in the figure, taking care to heat the parts uniformly all around. When a quantity of the solder has been caught in the cloth it should be worked

around onto the top, then more solder poured on this, catching the surplus with the cloth, as before, and heating the under side with it. When the solder on the pipe has become so hot as to be plastic, and is inclined to slide or drop off, and if it is certain that the surfaces are thoroughly tinned, and that the pipe is sufficiently hot to maintain the solder in a plastic condition long enough to perform the necessary work, and also that there is enough plastic solder to make a good joint, pouring should be stopped and the wiping begun. The colder pieces of solder which have set, or are beginning to set, are first thrown off the joint, then the edge of the cleaned parts which limit the ends of the joint are found, and the solder is formed into the shape desired, hollowing the cloth for that purpose. At the time of forming the joint,



FIG. 210.

all of the superfluous solder should be thrown off. The joint is then finished by working the cloth around from bottom to top, on both sides, and by finally drawing the cloth lightly across the top. This movement frequently leaves some solder projecting over onto the soiling, as shown at *a* in Fig. 210. This should be broken off as soon as formed, by lifting it with a knife-blade. It should not be cut off with a knife, since the lead pipe is still quite soft, and the blade is very apt to cut into and weaken it.

Some workmen finish wiping with a very quick motion of the cloth, which throws the surplus solder tangentially from the joint and leaves the line of finishing scarcely visible. This method, however, scatters the solder over the floors, where it picks up impurities.

When the wiping is completed, the joint should be cooled quickly by blowing a spray of water on it, to save time, because the joint must not be handled until it has cooled.

Rapid cooling also chills the surface and prevents the tin from separating from the lead in cooling, and settling to the bottom of the joint. It also improves the appearance of the joint by making it bright.

The liability to overheat the pipe and burn holes in it increases with its thinness and diameter.

789. In Fig. 211 is shown the manner of wiping a joint in a concealed place, the joint in the pipe *B* being out of the sight of the workman. This is done by placing a candle *A* so as to illuminate the back of the pipe, and two mirrors *C* and *D*, so as to reflect the image of the pipe. The formation of the joint must be governed mainly by feeling the solder while working.



FIG. 211.

Care must be taken, in doing this kind of work, to spread the solder well over the soiled parts of the pipe, otherwise a hole may be burned through the top of the joint. Solder will then enter the pipe as shown at *E*. Paper should be spread underneath the pipe to catch the surplus solder which is sure to fall off in such work, as shown at *F*.

Joints in large horizontal pipes may be wiped in several heats, or two men may operate simultaneously, one on each side. The open ends of the pipe are first closed to prevent a draft of air through it, so as not to convey heat from the joint to the outer atmosphere. Molten solder is then carefully poured upon the shaved ends until enough adheres to form the joint. The temperature of the pipe near the joint and the solder upon it is then raised to the melting point of

the solder by a gasoline torch similar to that shown in Fig. 167. The torch flame is then suddenly withdrawn, and the now plastic solder is easily formed into the proper shape. Should the solder begin to set before the joint is entirely wiped, more heat can be applied by the torch. Joints over four inches in diameter are seldom found in modern house plumbing.

790. Tee Branch Joints.—The manner of making a T branch joint is shown in Figs. 212, 213, and 214. A hole should first be bored in the main pipe with the tap borer, and then the edge turned outwards with a bending pin *C*, as shown in Fig. 212, care being taken not to form an edge *B* projecting inwards. The outwardly turned edge should then be shaped by the turn pin into a cup to receive the end of the branch pipe, which should be beveled and shaved as



FIG. 212.

for an ordinary straight joint. If possible, clamps should be used to draw the joint together. The joint is then wiped as in the case of a plain straight joint, except that the joint is to be finished at the bottom instead of the top. The finishing is done by drawing the cloth from *A* towards *B*, in Fig. 213, and then immediately cooling the joint, to prevent the tin from falling to the under side, where it will either fall off entirely, thereby leaving a hole behind, or will hang on in the form of a "teat" or bulb.

791. In Fig. 214 are shown two sections of a branch joint in which the correct and incorrect forms of preparing and wiping these joints are shown.

At *D* the cup in the lead pipe projects too far, and also the solder is misplaced, too much of it being under the cup,

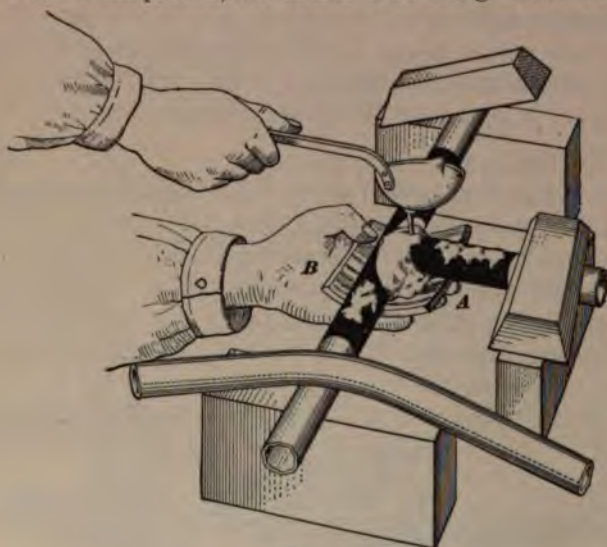


FIG. 213.

where it is not required, and too little above it. The lead protruding through the solder weakens this part of the

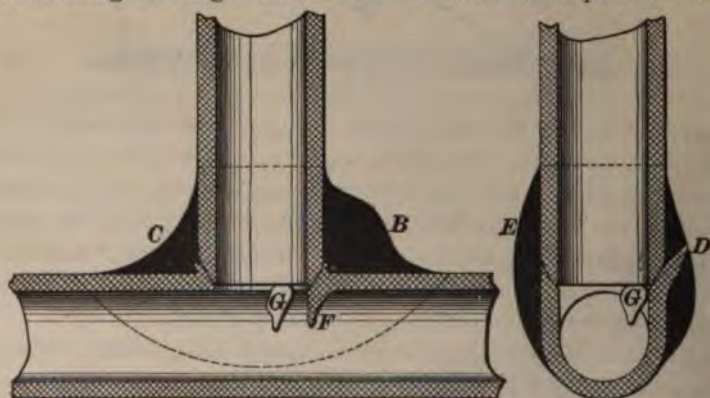


FIG. 214.

joint. The side *E* shows how the cup should be fitted, and the form of the solder when finished.

At *B* too much solder is applied, and, consequently, some of it is wasted. This form of wiping conveys the idea of poor workmanship.

The side *C* shows the proper curve that should be given

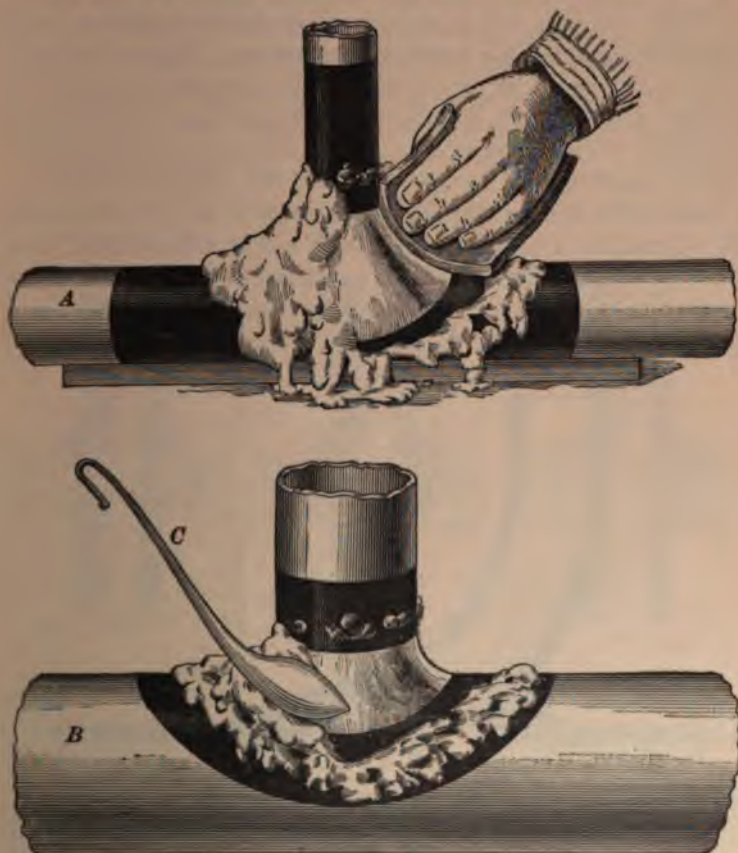


FIG. 215.

to the solder at this part of the joint. It is stronger than the pipe, and has a better appearance than the side *B*.

At *F* is shown the edge of the lead which has been driven into the pipe during the preparation of the joint. This should have been cut off before the pipes were put together

and wiped, or, better still, it should never have been formed. (See Art. 790.) At *G* is shown a bead of solder which has flowed into the pipe through a bad fit in the cup. These should be carefully guarded against.

792. In Fig. 215 is shown the manner of **wiping a T branch joint in an upright position**. If the main pipe is small, it should be placed upon a narrow strip of wood, as shown at *A*, to raise it sufficiently high from the bench to facilitate wiping, and if it is large, as shown at *B*, it may lie flat on the bench.

The solder is usually poured upon the joint with the ladle. Some plumbers prefer to splash it on at first with a thin piece of wood, called a **splash stick**, to guard against burning holes in the pipes. When the joint is sufficiently hot and the solder begins to flow off, the cloth is applied and

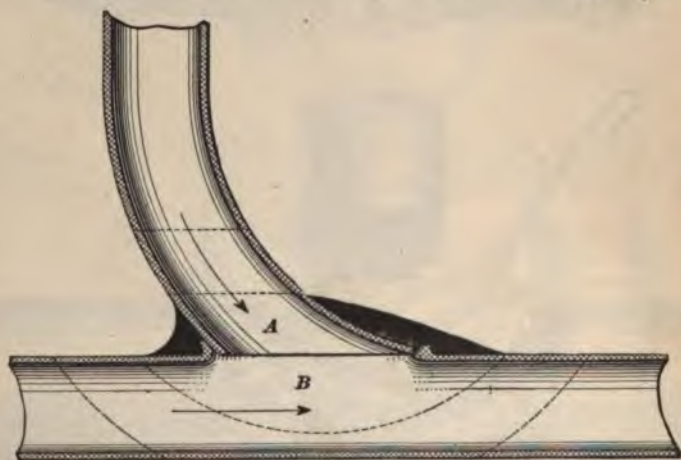


FIG. 216.

used as shown in the upper figure, finishing the joint as shown by that part at the finger-tips.

On large pipes, if the operator can not accomplish the wiping before the solder begins to set, a tank iron *C* is often used, as shown in the lower figure, to maintain the proper heat.

793. T Y Branch Joint.—In Fig. 216 is shown a T Y branch joint. This form of joint should always be wiped on waste pipes. The arrows show the direction of the flow of the water. A common right-angled branch joint does not permit the waste water to flow away with sufficient freedom. The waste water is apt to back up and leave deposits of grease and refuse, which eventually choke the pipe. Joints like this are usually wiped upright, care being taken to fit the pipe *A* so that it can not slip into *B* while being wiped.

794. Flange Joints.—The flange joints shown in Fig. 217 are made by flanging the end of the lower section of pipe over the board *R*. The upper section is beveled and

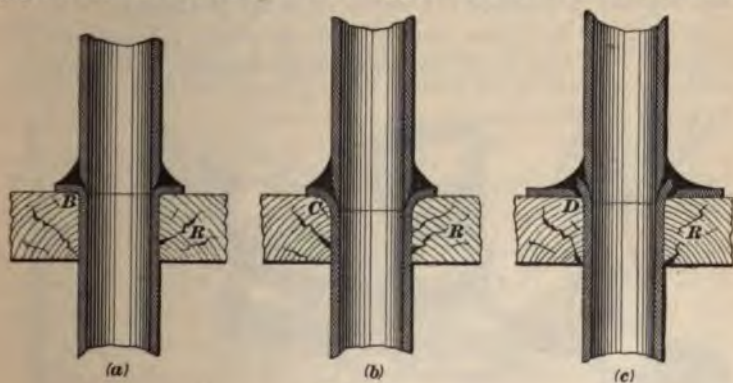


FIG. 217.

prepared as for an ordinary joint. The solder is applied with the ladle and is wiped to the shape shown, with the cloth.

The section (*a*) shows a square corner at *B* which should be avoided; the corner should be rounded as shown in section (*b*) at *C*.

When a heavy weight is to be borne by the flange, it should be reinforced by means of a lead ring or flange *D*, as shown in section (*c*). This should be shaved on the top and soiled on the outer edge and bottom, and must be laid upon the board before the pipe is flanged over. Care must be taken that the flanged part of the pipe is thoroughly tinned

before proceeding to wipe. When making flanged joints against finished walls or on floors, the woodwork should be protected by sheets of thick paper, as otherwise the hot solder will scorch or disfigure it. The flanges of sections (*a*) and (*b*) are liable to be thinned too much, or even split in flanging them over on the board, and on account of this these joints are usually made too narrow. When a separate flange or ring, as shown at (*c*), is used, a wider and much neater joint is obtained. Only this latter form of flange joint should be used.

795. Upright Wiped Joints.—The process of preparing joints for wiping in an upright position is similar to that already explained for joints in other positions.

In Fig. 218 is shown the manner in which a brass ferrule is joined to a lead waste or soil pipe by wiping the joint in an



FIG. 218.

upright position. The vertical section at the right shows the construction of the joint. The ferrule *F* is prepared by first tinning its upper edge, also its outer surface to a distance of about 1 inch below the top edge.

The lead pipe *B* should be shaved to about the same height above the edge of the ferrule, and a half inch or so below it, allowance being made for the projection of the pipe beyond the lower end of the ferrule. The pipe should then be slipped through the ferrule and doubled over, as shown in the

section at *D*, the lead extending upwards on the ferrule about $\frac{1}{4}$ inch. The pipe should then be placed upright on a bench, as shown, and braced in position. After fluxing, small quantities of solder should be applied with a splash stick until the shaved surfaces are covered. After this the solder may be poured on with the ladle, retaining it in place with the cloth until a sufficient quantity of plastic solder has been obtained, and then the solder may be formed into the proper shape with circular sweeps of the cloth, as shown in the figure, making the last movement across the joint and downwards. Care should be taken not to leave too much solder at *S*, since it will interfere with the calking operation when joining the lead pipe to an iron drain or soil pipe.

The waste solder *A* which falls upon the bench or paper under the ferrule should be detached from the work before it becomes set. If it sets before it can be removed, a hot iron may be used to divide it.

When wiping large upright joints, the heat may be applied by a tank iron, a blowpipe, or a gasoline torch, as circumstances may require. Two or more men may be employed on the same joint at the same time in order to finish it in one heat, or one man may do it in several heats. If the means at hand for heating the joint are sufficient, there is no more difficulty in wiping large joints than in small ones.

When joints are to be wiped in **upright pipes** which are already in position, a **collar** should be attached temporarily to the pipes directly under the joints, so as to catch the solder and to raise the temperature of that part of the pipe under the joint.

796. In Fig. 219 is shown a piece of lead pipe with a collar *A* in position, which is supported by a cord *C* tied around the pipe. The collar should be cut to a pattern about similar to *F*, so that when it is formed around the pipe the points *g* and *g* can be doubled over and locked together, as at *D*, to prevent it from spreading apart when the solder falls into it.

These collars are best when made of sheet lead, as this metal is very pliable and has no spring to it. The inner surface of the collar should be coated with soil to prevent the

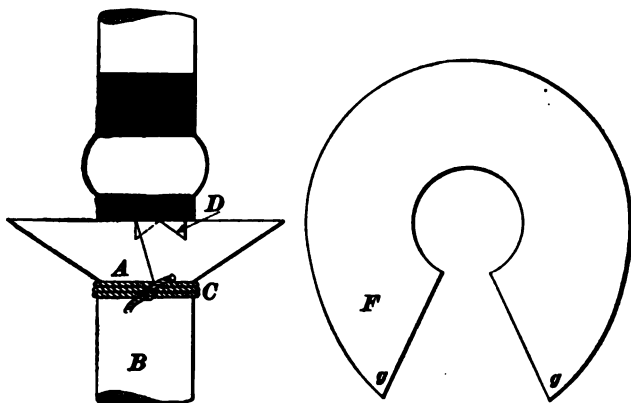


FIG. 219.

solder from adhering to it. The same collar can be used over and over again by simply soiling its inner surface upon each application. Paper collars are sometimes used, but they are not so satisfactory.

797. Blowpipe Soldering.—Blowpipe soldering is done chiefly on small tubing and other small articles. The tube is prepared in the same manner as a cup joint. The solder is applied by holding a thin strip of it in the flame close to the joint, so that the molten part will fall into the cup. When the cup is full of solder, it is sweated by heating the joint all around, and causing the solder to flow, which makes a clean and strong joint.

In Fig. 220 is shown the manner of making a blowpipe joint, in which *A* is the blowpipe blown by the mouth, *B* an alcohol lamp, and *C* the pipe in which the joint is to be made.

By means of the blowpipe the alcohol flame *D* is blown against the sides of the pipe as shown. To obtain the best results the blowpipe should be held in such a position that the portion *E* of the flame *D* when blown against the pipe

will be noiseless. The wind pressure should be steady and its point of application to the flame should be constant. This manner of soldering is best adapted for thin tubes of block tin or tin alloys whose temperature of fusion is low, as the heat can be applied to the pipe or to the solder at will. The

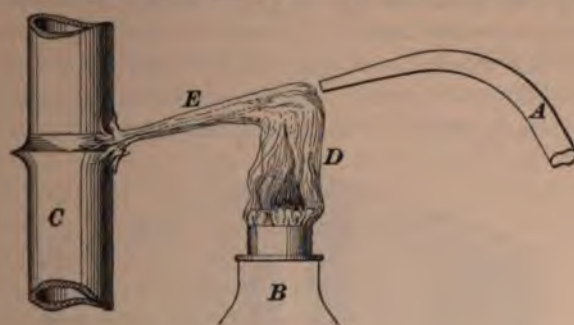


FIG. 230.

pipe can be uniformly heated to the fusion point of the solder with little danger of burning it. Care must be taken to keep the flame shifting about so as to avoid too much heat at one spot, as otherwise ugly holes are apt to result.

WIPING SEAMS IN TANK LININGS.

798. The inside of house tanks is generally lined either with sheet lead or sheet copper tinned on one side. The **seams** of the lining, or the points where the sheets forming the lining are joined, are usually wiped with solder to make them water-tight. The sheets are cut to fit the inside of the tank, so as to have as few seams as possible.

799. Lead linings are usually prepared outside of the tank and then put into place. In doing this the lead is first rolled out on a flat surface and then cut to fit the tank. The edges which are to be wiped are then soiled to a width of about four inches, and are shaved and covered with tallow to a distance of about one inch from the edge. In small tanks the seams are usually butted together, and in large

ones they are lapped. When they are to be lapped, about one-half inch should be allowed for lapping, and it is usual to shave the sheets in position.

After the edges of the sheets are properly shaved, soiled, and fitted into place, they should be firmly secured by means of *tinned clout nails* driven through the lead into the wood-work at intervals of about 2 inches. This is to prevent the edges of the sheets from bulging by their expansion when heated. The sheets must be otherwise supported, as explained in Art. 801. The wiping should be commenced at



FIG. 221.

the top of the upright seams and worked downwards, pouring the solder from the ladle against the seams by means of a pouring stick. A pouring stick is simply a strip of wood of convenient length, having a groove cut in the upper side to guide the solder against the seam. The tank iron is commonly used to maintain the proper working heat and to tin the cleaning. The iron should be worked up and down against the seam through a sweep of about 18 inches, and when the solder begins to flow it should be wiped to the proper shape with the cloth. Alternate sweeps should be

made with the iron and cloth until the bottom is reached, care being taken to prevent the solder from falling down.

In Fig. 221 is shown an inside corner of a lead-lined tank in which the upright corner seam is wiped. In wiping upright corner seams which rise from the horizontal corner seams, as shown in the figure, a short distance of the latter should be wiped as shown at *A*. This is done to facilitate the easy connection in wiping the horizontal corner seams. In wiping the horizontal corner seams, the surplus solder from the upright seams, as at *B*, is first melted by the tank iron and then spread in the corner with the cloth. The tank iron is then used to raise the seam to the proper heat, and the wiping is continued with the cloth. Care should be taken to work the surplus solder well ahead and allow none to spread unnecessarily. The nail heads should be well covered with solder, as otherwise a leak will be the result.

800. In lining house tanks with **sheet copper**, the seams, which can be made in a horizontal position, are usually soldered with a bit, but all upright seams which must be made in position should be wiped in a manner similar to that described above, with this difference, that no soil is used. If a tank iron is used to maintain the heat of the seams while wiping them, a strip of paper should be pasted on the copper for the same purpose that soil is used on lead. If a gasoline torch is used to raise the heat of the seam, the tinned surface of the copper is left uncovered. The seams of copper linings should always be **locked** or **double-seamed** in such a manner that the tinned surface of the copper shall come together in the lock as explained in Art. 781.

If the copper sheets are not tinned, the edges must first be tinned to a suitable width with the solder bit, using chloride of zinc as the flux. The upright seams are secured to the tank with tinned nails to prevent them from bulging while being wiped.

The application of the solder to the seams and the wiping

of them are the same as for those in lead-lined tanks, except that the solder must be worked ahead, as otherwise it will adhere fast to the tinned surface of the copper sheets. If a tank which is lined with tinned copper is properly wiped, the seams will be smooth and almost invisible.

LINING TANKS, SINKS, ETC.

801. The thickness of the metal sheets which are used for lining tanks should vary according to the depth of the water. For a tank about four feet deep, sixteen-ounce or

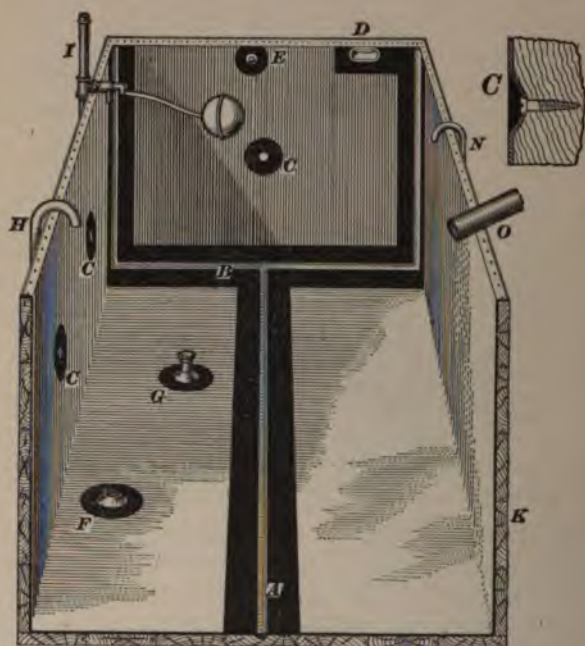


FIG. 222.

twenty-ounce copper, or seven-pound sheet lead, would be proper. The size of the parts into which the lining is divided is governed by their weight and the facilities at hand for lifting and handling them, etc.

For example, a tank three feet six inches deep inside, four feet ten inches wide, by six feet ten inches long, is to be lined with seven-pound sheet lead. Fig. 222 shows how the lining should be divided. Allowing one inch for lapping over the top edges of the tank, also one inch for lapping at the corner seams, one side and a half of the bottom will weigh over 280 pounds, and each end will weigh over 120 pounds; consequently, these pieces are about as large as can be conveniently handled, especially in so small a space. In a smaller tank the bottom and sides may be put in in one piece. In the figure the black margins show the soiling, and *A* and *B* show the wiped seams. The flat seam *A* may be wiped or floated as previously described.

To support the sheets in place, they should be doubled over upon the top edges of the tank and be securely fastened with tinned nails. The sheets should be secured to the sides of the tank at intervals, as shown at *C*, to prevent bulging inwards. The wood at these points is gouged out, forming a countersink about one-half inch deep, as shown by the section at the right. The lead is dressed into the cavity and is fastened with a brass screw which has been previously tinned. Solder is then wiped over the screw, filling the cavity flush, which then makes the attachment secure and water-tight.

In the case of large surfaces, these **solder dots**, as they are called, should be located from 24 to 36 inches apart.

Sheet-copper linings should be similarly secured to the sides, the fastenings being from 3 to 4 feet apart upon large surfaces. For tank linings, copper should always be tinned upon that side which is touched by the water.

In lining bath-tubs, etc., where the copper will encounter hot water, it will expand considerably, and if the sides or bottom are flat, it will bulge. This should be prevented by means of solder dots at the points where the bulging is likely to occur.

For covering the top board of pantry sinks, etc., sheet tin, rolled from pure block tin, is preferable to lead, zinc, or copper. It tarnishes very slowly, is easily kept clean, is

durable, and it easily receives a high polish, which makes it resemble silver.

802. In Fig. 223 is shown the manner of cutting the block-tin sheet to cover the wooden top of a pantry sink,

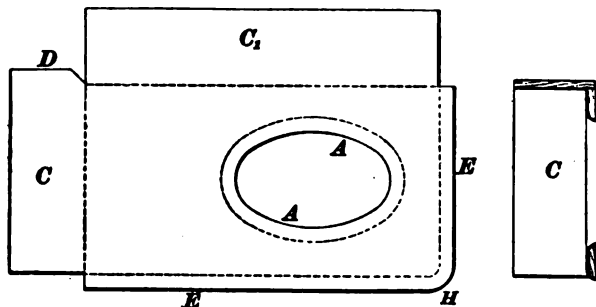


FIG. 223.

which is shown by the dotted lines. The sheet is cut at *E* and *E* larger than the top, and at *A* and *A* smaller than the hole in the top, so that it may be bent around the edges and nailed underneath, as shown in the section at the right. Sufficient metal is left on at *C* and *C*₁ to form *upstands* or *splash plates*, *C* being of such shape that when the plates are turned up the part *D* can be bent around *C*₁ to form a lap joint in the corner. This joint is then neatly soldered with the blowpipe.

The sectional view shows the top covered and *C* and *C*₁ bent up in position. The tin can be bent neatly over the

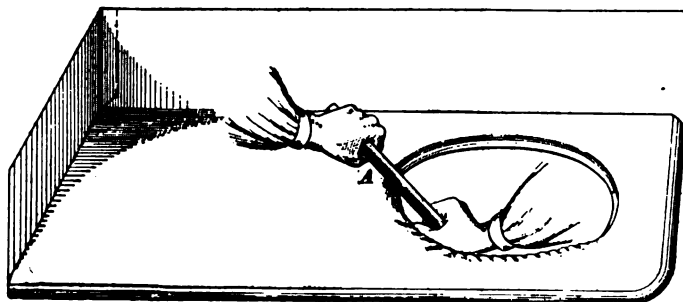


FIG. 224.

outside corner *H* by smoothing it down with a hot flat-iron.

The margin of tin allowed at *A* and *A* can be worked down and under the cover by means of a warm, smooth, round bar *A*, Fig. 224, which shows the manner of applying it.

BRAZING.

803. Brazing is a process of joining two or more metals by a solder known as **hard solder**, whose temperature of fusion is much higher than that of soft solders, and whose tenacity is greater. Hard solders, as shown in the table in Art. 771, are composed of alloys of copper, zinc, tin, silver, etc. Only those metals whose temperature of fusion exceeds that of hard solders, such, for instance, as iron, copper, and brass, can be brazed. In this class of soldering, the temperature required to fuse the solder is so high that soldering bits or wiping cloths can not be used.

The heat is usually applied to the parts to be brazed by means of an intensely hot blowpipe flame.

Small articles may be brazed with a mouth blowpipe, but the sizes of pipe usually handled by plumbers require a compound blowpipe, which uses common illuminating gas for fuel and is blown by a blast of air from a bellows. Larger jobs having a considerable weight of metal to be heated are executed in a forge fire. For brazing collars, etc., upon 2 or 3-inch tubing, the fire is arched over with coke, thus making a hot chamber in which the work may be uniformly heated.

804. In Fig. 225 is shown a very convenient form of **blowpipe** to be used in connection with a bellows. This



FIG. 225.

is composed of a gas-pipe *B* having a lever handle controlling cock attached; an air or blast pipe *A*, also having a lever handle controlling cock attached, and an iron pipe nozzle *C* joined by a special casting to the pipes *A* and *B*.

805. In Fig. 226 is shown a form of **blower** suitable for supplying air to the blowpipe shown in Fig. 225. It is

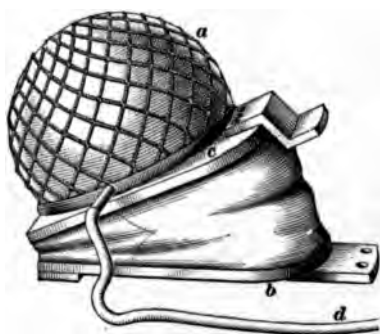


FIG. 226.

composed of a single-acting bellows having an air inlet check-valve in the bellows, situated on the inside of the bottom board *b*, and another on the upper side of the pressure board *c* and within the rubber storage bag *a*, which is enclosed by a network to prevent its being inflated too much.

The bellows are operated as follows: The top board, which is hinged at the lower end and supported by a spring within the bellows, upon being pushed down with the foot compresses the air within the bellows and forces a portion of it through the upper check-valve into the rubber bag. When the weight of the foot is relieved from the pressure board, the bellows will be again filled with air by the spring raising the pressure board. The pressure of the foot of the workman, being repeatedly applied to the pressure board, will in this manner fill the rubber bag with compressed air, which flows to the blowpipe through the rubber tube *d* when the air cock at the blowpipe is open. The elasticity of the rubber bag serves to equalize the pressure of the blast.

This form of blower is capable of furnishing a strong and nearly continuous blast through a jet $\frac{1}{4}$ inch in diameter.

The blowpipe should be connected by rubber tubing to a gas-burner or other supply and to the blower, care being taken that the bore of the tubing is large enough to avoid excessive friction.

Air is mixed with the gas before it is consumed for several reasons, but chiefly because an all-gas flame is low in temperature and gives off products of combustion which not only tarnish the metal, but also cover it with a coating which separates the flame from the metal being heated.

The combustion of gas and air mixtures is more fully treated upon in the section on Gas and Gas Fitting.

The gas should be turned on first, and be lit at the jet; air is then admitted gradually until the flame is brought to the proper size and color. If too much gas is admitted the flame will be yellow, and it will blacken the work by depositing a film of carbon upon it. If too much air is admitted the flame will be short, ragged, and noisy, and the temperature will be too low to properly heat the metal. The flame is at its greatest heat and best condition when it burns with a pale blue or bluish green color, without any white or yellow parts.

The article to be brazed must be well supported, and the seam should be well bound together with iron wire to prevent the edges from warping out of place when heated.

806. To braze joints, *spelter* or *hard solder* is placed over the seam in such a manner that when it fuses it will flow by gravity into the seam. *Powdered calcined borax* is then sprinkled over the seam for a flux, and the blowpipe flame is applied chiefly upon the thick parts of the metal at first, the idea being to heat the mass uniformly to the temperature of fusion of the spelter.

The heat of the metal is then increased, care being taken to avoid giving much more heat to the spelter, otherwise it may be burned or spoiled. As soon as the metal is hot enough, the borax will fuse and flow over the parts, and as the heat rises a little higher the spelter will melt and flow into the crevice and adhere to the faces of the joint. The spelter will sweat into a crevice for a considerable distance if the metal is clean and is properly heated through.

The melting point of the spelter and of the metal to which it is applied may not differ more than 300° or 400°; consequently, great care must be exercised to avoid overheating the metal. The heat must be applied uniformly, otherwise the work is liable to warp, and if the flame is directed upon one spot too long, a hole is likely to be burned at that point. When brazing metals which have a low melting point, the

blowpipe flame should be promptly withdrawn as soon as the spelter flows.

Sometimes the composition of brass tubing and sheet brass is so uneven, or is so contaminated by chemical impurities, that brazing can not be satisfactorily performed upon it. Such material may be used, however, for jobs which require only soft soldering.

Brass tubing is very brittle when hot; consequently, it should not be moved until it has cooled. The process of

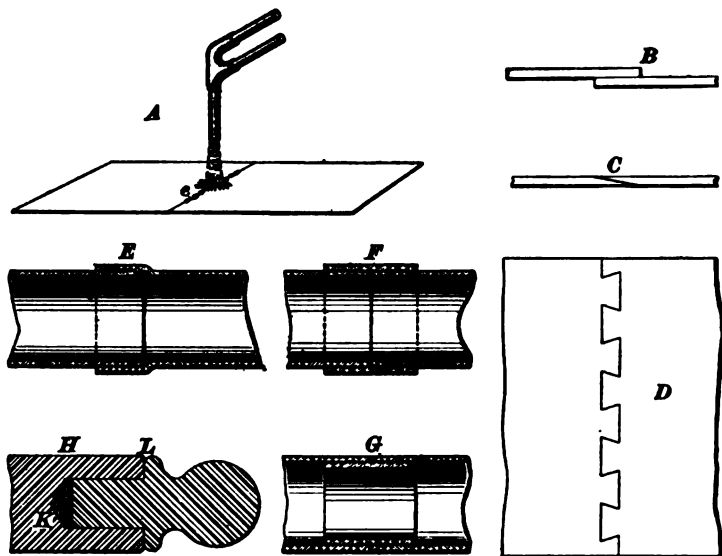


FIG. 227.

brazing softens the parts that are heated, and these do not return to their original hardness upon cooling.

Small articles may be heated in a charcoal fire without the blowpipe. A blast may be used to urge the fire, if needed. Large or heavy jobs may be heated in a forge fire, for which clean coke free from sulphur is commonly used. To braise successfully, three things are required: First, *a proper degree of heat, neither too low nor too high*; second, *uniform heating*; third, *proper fluxing*.

In selecting the spelter to be used, that which will melt

at a temperature lower than the melting point of the metal to be brazed must be chosen.

When brazing pieces to brass tubes which are made with a brazed seam, it is unsafe to use spelter, because of the liability of opening the seam. A more fusible solder, such as silver solder, should be used.

807. In Fig. 227 is shown a variety of joints suitable for different jobs. *A* is called a **butt joint**, *e* being the lumps of spelter placed in position ready for fusion. The strength of this joint is small, being in proportion to the actual area of the edges which are united by the spelter.

The strength is greatly increased by **lapping** the plates as at *B*. An equal amount of strength may be secured and the appearance greatly improved by **beveling**, or **splaying**, the edges, as at *C*, provided the plates are thick enough to permit the beveling to be extended to a sufficient width.

The strongest joint for sheet metals is made by **dove-tailing** the edges together before brazing, as at *D*.

808. **Circular butt joints** may be strengthened by means of a band put on externally, as at *F*; or by an internal ferrule, as at *G*.

Thin tubing may be joined by a **slip joint**, as at *E*, by first annealing one of the ends and forming it into a socket. The end is flared out by means of a drift plug, care being taken not to split the pipe, after which the metal is expanded by hammering, until the other end will enter properly.

At *H* is shown a knob brazed to the end of a rod. To do this job properly, the spelter must be made to flow into the socket and secure the shank of the knob. A good job can not be made merely by securing the edges at *L*. The rod should be held vertically in a charcoal fire until the socket is well heated, at the same time heating the knob also. Borax and spelter are then placed in the socket, and as soon as the spelter is melted the shank of the knob should be inserted and pressed into place. The spelter will flow outwards by being displaced by the shank and will make sure of filling the entire joint; or, the space *K* at the end of

the shank may be filled with spelter as shown, and the knob inserted. If the knob and socket are then heated in an inverted position, the spelters in *K* will flow by gravity around the shank and sweat down to the rim *L*.

JOINING CAST-IRON PIPES.

809. Cast-iron pipes for drain, soil, and vent pipes, and their fittings, are joined together by **spigot and socket**

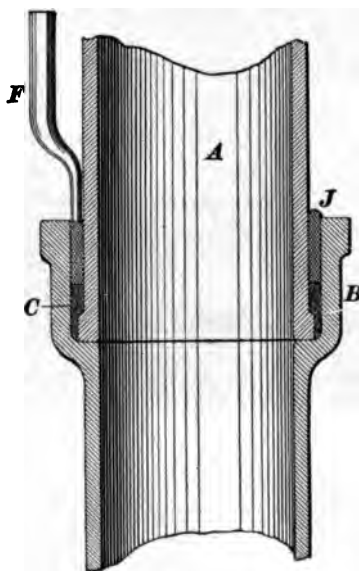


FIG. 228.

joints. The spigot end *A* of one piece is inserted into the socket or hub *B* of another, as in Fig. 228, which shows how a joint is made in an *upright pipe*. A strand of oakum, which should be moderately twisted, is first laid in the bottom of the socket and is packed tightly into place. More oakum is added and calked tight, until the socket is about one-third full, as at *C*.

The oakum must be thoroughly packed and driven home with a *yarning*, or *long calking tool*, before the molten lead is poured into the socket, otherwise the lead will drive

in too far when it is calked and the work will be spoiled. In a joint of upright pipe the lead should be poured into the socket until it stands about $\frac{1}{8}$ inch above the rim, just on the verge of overflowing, as at *J*. The socket should always be filled at one pouring. If it is only partly filled at one pouring, the lead will set before more can be obtained from the pot, and the result will be an imperfect joint. The object of the excess of lead at *J* is that it may not be calked in beyond the edge of the hub. The stiffness and durability of the joint depend upon the perfect and complete filling of the socket to the extreme edge.

The process of calking the lead or oakum should be begun at the most difficult or inaccessible parts of the joint, so that these parts will be compressed still more when the other parts of the joint are being calked. The staving tool or lead calking tool *F* should be run around gently the first time, then around again, with heavier blows of the hammer to drive the lead solidly home. Each blow of the hammer increases the pressure inside of the hub, and judgment must be exercised to avoid cracking the hub by over pressure.

The staving tool should not be tapered, because it is liable to wedge between the hub and pipe, and strain the hub so that it will crack when the calking of the lead is about

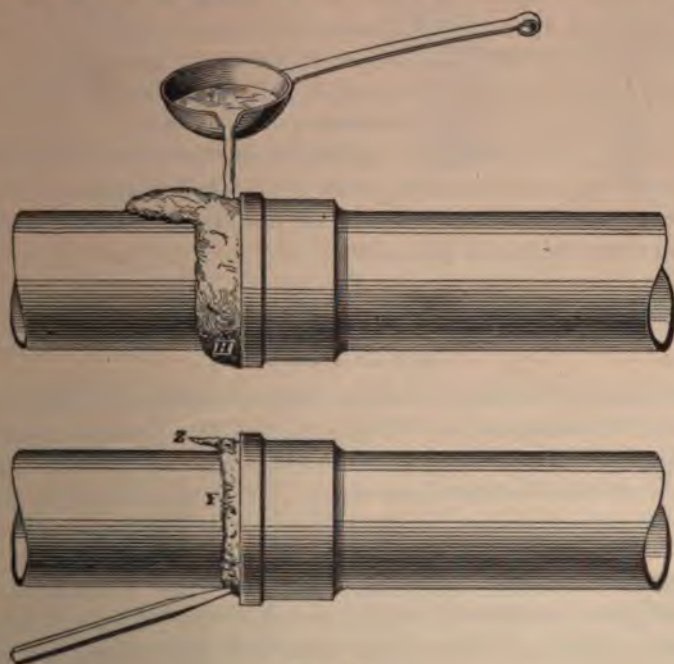


FIG. 229.

completed. A cracked socket should always be removed and be replaced by a new pipe.

810. In making *horizontal joints*, or joints on *inclined pipes*, the outer end of the socket must be closed by a band or joint runner, as shown in Fig. 229, at *H*. This is usually made of clay, strengthened by a piece of rope, which is embedded in it. A *gate*, or pouring notch, is left at the top, and molten lead is poured into it from the ladle, as shown. The working face of the clay is shaped so that the lead will take the form shown at *Y*, the projection *Z* being the *gate*. Pouring should not be stopped until the gate is full and remains so. Particular care should be taken before pouring that the socket be wholly free from moisture, otherwise an explosion is very likely to occur by the moisture being suddenly converted into steam while the lead is running in. These explosions frequently burn the workman by throwing the molten lead upon him, and sometimes even destroy his eyes. To guard against this danger, the workman should always stand behind the hub, so that if a *blow* does occur, the hot lead will be projected from him.

The clay band must be tightly secured, because the pressure of the melted lead in sockets of large diameter is considerable; and if it starts the clay a little, the lead is liable to run out and spoil the joint.

CONNECTING PIPES OF DIFFERENT MATERIALS.

811. Connections may be made between *lead pipe* and *cast-iron drain pipe*, as shown in Fig. 230. The end of the lead pipe *A* is stiffened by means of a brass collar or *ferrule D*, to which it is wiped, as at *B*. The end of the lead pipe is doubled over upon the outside of the ferrule, as shown at *C*. The socket is then closed with oakum and lead, as described above. The object of the brass ferrule is to strengthen the lead pipe and prevent the pressure due to calking the lead and oakum into the socket from bulging the pipe inwards or otherwise distorting it.

812. *Wrought-iron pipe* may be connected to *cast-iron pipe* by threading the end of the wrought-iron pipe as for a

screw joint, and securing it within the socket of the cast pipe by calking with lead and oakum in the ordinary manner.

If the joint is required to resist heavy pressure, the wrought-iron pipe should be heated in the forge fire and flanged over. The outer diameter of the flange should be as large as will easily enter the socket of the cast-iron pipe. The flange stiffens the end of the pipe, and makes a very strong joint.

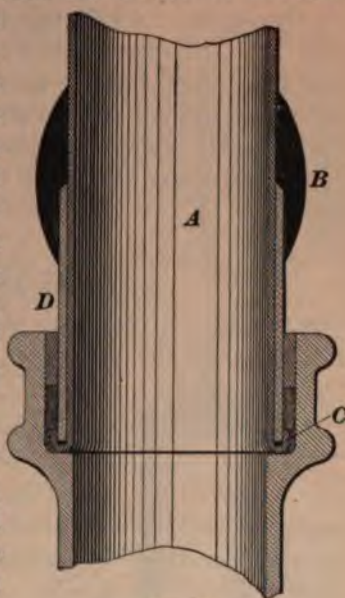


FIG. 230.

813. To connect *wrought-iron pipe to earthen drain pipe*, a flange or collar of four-pound sheet lead, or heavier, is made to slip over the end of the iron pipe. This collar is set firmly down to the bottom of the socket, and the hub is then filled with a mixture of Portland cement and sand in equal parts. The lead collar prevents the cement from entering the drain pipes.

814. A *lead waste pipe* may be connected to an *earthen pipe* by a cement joint. A lead flange is wiped on the waste pipe about three inches above the end. This is seated in the bottom of the socket, which is then filled with Portland cement and sand.

815. *Rain-water leaders* of galvanized iron or copper, located on the outside of a building, are generally connected to *earthen or iron drain pipes* by means of cement joints. The leader should extend a little below the bottom of the socket of the pipe. If the leader is much smaller than the pipe, a lead collar or flange may be used to prevent the cement from dropping into it, otherwise a little oakum may

be packed in the bottom of the socket. If the leader is run on the inside of a building, it should be connected to an iron pipe. In this case the end of the leader should be strengthened by a brass ferrule, as shown in Fig. 230, and be calked with lead and oakum in the ordinary manner.

All inside leaders should be fitted up water-tight. The joints and seams should all be well soldered if sheet metal is used.

SUPPORTS FOR PIPES.

816. Lead pipes two inches in diameter and less, which run against walls, etc., are usually supported by means of flanges, or **pipe tacks**, which are soldered on to the pipe at convenient intervals, and are fastened to the walls with common wood screws, as illustrated in Fig. 231, which shows a $\frac{3}{4}$ -inch lead pipe *a* secured to a wall or pipe board *b* by *molded pipe tacks* *c, c* and 1-inch wood screws *d, d*, etc.

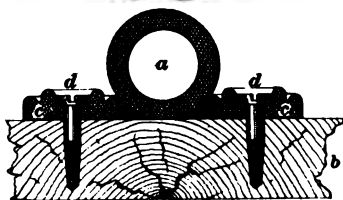
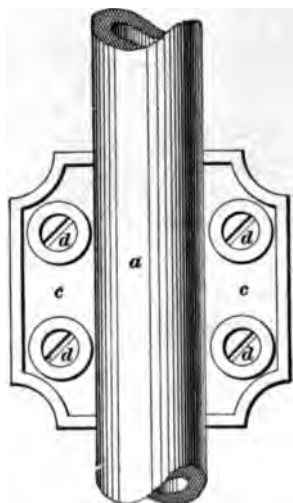


FIG. 231.

The tacks are made of old lead slightly hardened, with a few old wipe joints mixed in. They are cast in brass molds which can be bought from dealers of plumbing material.

817. Pipes of over 2 inches in diameter are best supported by means of broad **bands**, such as shown in Fig. 232, which are attached at intervals of about 3 or 4 feet. The width of the bands, along the line of the pipes, measured for pipes of 2, 3, or 4 inches diameter, should be about 6, 8, or 10 inches,

respectively. An oblong hole *c* is cut in the front of the band, and is filled with hot solder and wiped to the face of the pipe. The side flanges of the band are wiped to the face of the pipe, as shown at *b*. The band is shown secured to a stone wall by flat-head spikes *a* driven into wooden plugs *d*, which have been previously driven into holes cut into the stonework.

If the temperature of a lead pipe which is supported by rigid fastenings is maintained nearly uniform, as is the case of the cold-water supply pipes, the pipe can only be changed in form by its own weight, the jarring of the building, etc.

If, however, the temperature of the pipe is variable, as is the case of the pipes which supply hot water to the plumbing fixtures, the pipes will expand as the temperature increases, which causes them to bulge between their supports. If the pipes are vertical, they will bulge either from the wall against which they are secured or parallel with it. If they are horizontal or inclined, they will always bulge downwards and form pockets or sags. Lead is so very low in elasticity that when the pipe becomes cool, the sags are not entirely taken up by contraction, and upon every application of heat the sags will increase in size, particularly on horizontal pipes, until the lead becomes so thin near the points of support as to cause a leak. The leak generally occurs in a crack which is formed around that part of the pipe near the tacks.

Suppose that a lead waste pipe 2 inches in diameter, secured in a vertical position against a wall by hard metal tacks or lead bands, has a kink in it, and that hot water passes through the pipe periodically. It will be found that since the kink is the weakest part of the pipe, it will take up most of the expansion between the tacks on each side of it. This action subjects the kink to a cross strain, repetitions

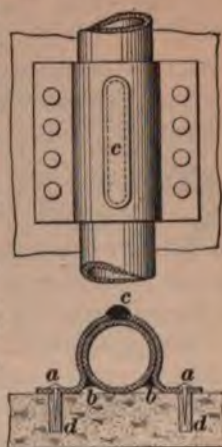


FIG. 232.

of which will soon overcome the cohesive strength of the lead and cause the metal at that point to crack. *Kinks should be carefully avoided in all lead-pipe work.* A kink in a lead waste pipe is a positive sign of slovenly, careless, or ignorant workmanship, and should not be tolerated.

818. When a hot-water pipe runs horizontally, it is better to support it upon a continuous ledge or shelf. It should have room enough laterally to bend and creep, and should be kept from working off the shelf by a suitable rim or flange along the edge of the shelf.

Lead pipes should not be supported by iron wall hooks or similar supports, unless they are protected by an extra thickness of sheet lead between them and the iron, because the edges of the iron will gradually cut into the lead and thus weaken the pipe.

819. The approximate spacing for tacks on lead pipes is given in the following table:

TABLE 37.

Size of Pipe in Inches.	Vertical Pipe.		Horizontal Pipe.	
	Distance Apart in Inches.		Distance Apart in Inches.	
	Hot.	Cold.	Hot.	Cold.
$\frac{3}{8}$	18	24	12	16
$\frac{1}{2}$	19	25	14	17
$\frac{5}{8}$	20	26	15	18
$\frac{3}{4}$	21	27	16	19
1	22	28	17	20
$1\frac{1}{4}$	23	29	18	21
$1\frac{1}{2}$	24	30	18	22

820. *Vertical pipes of lead* are usually supported, where they pass through floors, by means of a flange or collar, which is wiped to the pipe; or, a flange joint is made at that point. The diameter of the flange should be about two inches larger than that of the pipe, to give room for wiping.



FIG. 233.

821. *Wrought-iron pipes* may be fastened in place by common *iron drive hooks*, but where a good appearance is desired, they should be fastened with bands, or *straps*, which are secured to the walls by screws, as shown in Fig. 233. The strap *a* should be made of wrought iron, tinned.

822. *Brass pipe* may be similarly supported, making the bands of brass. It is usually supported, however, by specially made clamps or pipe hangers, which are first attached to the walls, the pipes being afterwards laid into them and locked there by closing the outer half of the clamp, which is hinged to the main body. Such supports usually hold the pipe at a little distance from the walls; this prevents vermin from lodging around them, and also allows them to be polished conveniently.

823. *Cast-iron soil and vent pipes* should be strongly secured in place. Vertical stacks should rest upon a solid support at the bottom. If an elbow occurs at the base of the stack, it should be provided with a flat foot, or **heel rest**, as shown at *a* in Fig. 234.



FIG. 234.

The weight of the pipe should be borne entirely by the base support. The pipe should be held in place by means of hooks or bands, which are placed at intervals of 5 feet or less, according to the nature of the work.

824. The pipe may also be secured against the face of a stone wall by means of a *wrought-iron band* *a*, as shown

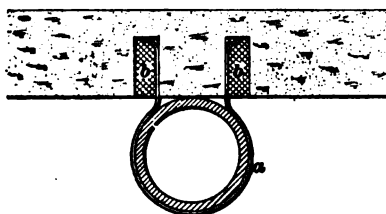


FIG. 235.

in Fig. 235. Two holes *b, b* are cut into the stone, and the ends of the band are calked in the holes with lead. This style of fastening is neat and reliable.

All hooks or bands should clasp the pipe close under the hub, or around it, and should not be placed midway between the joints, if possible to avoid it.

825. If the pipes stand in a chase, or groove, in the wall, they may be fastened by means of clamps, or **pipe rests**, *a*, which are secured in notches *b, b* cut in the wall, as shown in Fig. 236.

Care must be taken that the fastenings are so arranged that the pipe will be free to contract and expand with the

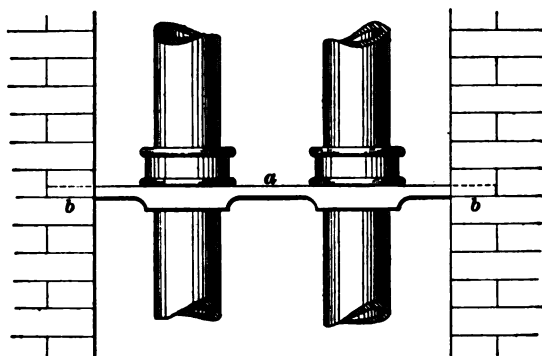


FIG. 236.

changes of temperature without loosening itself or tearing the fastenings loose from the walls. Buildings are always liable to settle, and this must be kept in mind when locating the pipe fastenings.

Iron drain pipes which run inside of basements or cellars

should be thoroughly supported by wrought-iron straps fastened to the beams overhead, or else they should be supported at short intervals upon brick piers, or by wall hooks driven into the brick or stone walls.

A substantial pier should always be placed under each stack. In all cases a firm support should be placed under the junction of the stack with the inclined drain pipe. All stacks should be supported independently of the main drain so as to relieve the inclined pipe of the weight of the stack.

FASTENING IRON RODS, BOLTS, ETC., TO STONework.

826. A hole about $\frac{1}{2}$ inch larger than the rod is first cut or drilled into the stone to a suitable depth, which will vary with the nature of the work, a common depth being from 4 to 6 inches. The end of the rod is notched or roughened in some way, then inserted in the hole, and the space around it is filled with a suitable cement, such as melted sulphur. If the connection is exposed to the weather, the exposed part of the iron should be coated with asphaltum or other water-proof compound.

The rod may also be secured by filling up the hole with melted lead and finishing by calking the lead. Care must be taken in calking to avoid splitting the stone. The junction of the lead and iron generates a galvanic action which corrodes the iron and gradually eats it away. This may be prevented by coating the exposed part of the iron with asphaltum.

Bolts may be secured to *marble* or *slate slabs* by the method shown in Fig. 237.

A hole is drilled in the slab *a* to the required depth, and is enlarged at the inner end, as shown, by means of suitable chisels. After the bolt is placed in the hole, melted lead is poured around the bolt. The lead is then gently

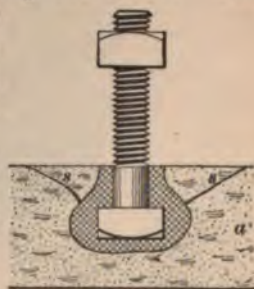


FIG. 237.

calked. If the lead is calked too much, the marble will break away, as shown by the lines *s*. Plaster of Paris is also used to fill the space around the bolt in cases where but little strain is likely to be put upon it.

827. Expansion Bolts.—Attachments may be made to stonework by means of expansion bolts, as shown in Fig.

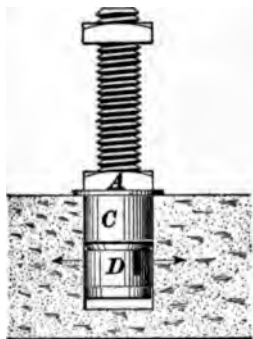


FIG. 238.

238. These bolts are provided with a loose ring *C*, having its lower edge beveled, and a notched ring *D* of soft metal. A hole is drilled in the stone large enough in diameter to fit the bolt closely, and the bolt is pushed in to the depth required. The nut *A* is then screwed down and the ring *C* is forced into the end of the soft ring *D*, which is thereby expanded against the sides of the hole. These bolts are less liable to split the stones than those which are calked with lead, be-

cause the directions of the forces exerted in securing this bolt are mainly in directions parallel with the surface of the slab, and in the middle of its thickness, as shown by the arrows.

PLUMBING AND DRAINAGE.

(CONTINUED.)

WATER AND ITS MANIPULATION.

MEASURING PRESSURE.

828. Water pressure is measured in pounds per square inch above atmospheric pressure by means of a **pressure gauge**. For pressures of about 100 pounds or less, an ordinary steam pressure gauge may be used; but for higher pressures, particularly if the apparatus shall be subjected to sudden shocks, specially made hydraulic gauges should be used.

829. In Fig. 239 is shown a pressure gauge adapted to the measurement of either steam or water pressures. It con-

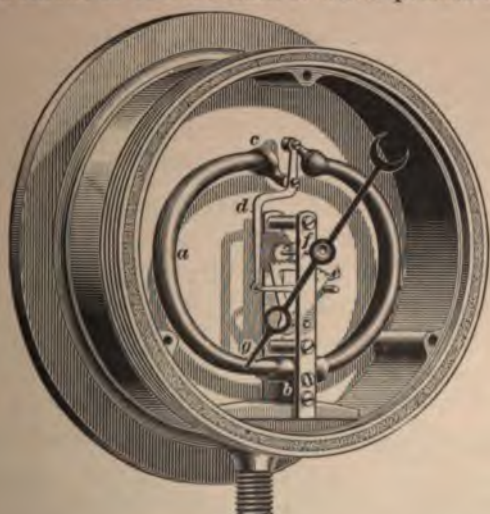


FIG. 239.

sists of a tube *a* of elliptical cross-section, which is filled with water and connected at *b* with a pipe leading to the

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vessel containing the liquid whose pressure it is desired to find. The other end *c* is closed, and is attached to a link which is in turn connected with a rack *e*; this rack gears with a pinion *f* on the index pointer *g*. When the elliptical tube is subjected to pressure, it tends to take a circular form of cross-section, and as a whole it straightens out slightly, throwing the free end out a distance proportional to the pressure. The movement of the free end is transmitted to the pointer by the link, rack, and pinion, and the pressure is thus recorded on the graduated dial.

830. A **vacuum gauge** indicates the pressure in pounds per square inch below atmospheric pressure. These gauges are seldom used by plumbers. They are useful, however, in ascertaining the pressures in the suction pipes of pumps, etc.

The pressure of water in the plumbing in any building or part of a building supplied from city mains can not be computed by the vertical height of the reservoir above the building, because the water in the mains is constantly flowing to supply a demand at factories, stores, dwellings, etc., in other parts of the city or town, and the pressure is always lower than that corresponding to the actual head; consequently, the pressure gauge referred to in Fig. 239 is often used to ascertain the actual pressures at the several points.

831. To compute the height water will rise, the gauge pressure being known:

Rule.—*Divide the gauge pressure by .43404. The quotient will be the height in feet.*

EXAMPLE.—A pressure gauge attached to a service pipe in the cellar of a building indicates a pressure of 23 pounds. To what height will the water rise in the plumbing system within the building?

SOLUTION.— $\frac{23}{.43404} = 53 \text{ ft., nearly. Ans.}$

Although this is the height to which the water would rise, it is advisable to have a surplus head of at least 10 feet above the highest fixture supplied from this pressure, so as to obtain a respectable velocity of discharge.

SOLVENT ACTION OF WATER.

832. Water rapidly corrodes iron, forming oxides of iron, some of which are soluble in water, but the insoluble red oxide is most conspicuous.

Water thus contaminated is not poisonous in small quantities, but is unfit for use because of its discoloration.

Water will also corrode lead, brass, and zinc, and form compounds which are very poisonous. Unfortunately, the presence of these poisons in water can not be detected by color, but only by taste or chemical tests. Water that can be used for domestic purposes is not affected by tin.

The water which exists in common soil is usually mixed with a small percentage of vegetable and mineral acids which originate in the decomposition of leaves, etc., upon the surface, and it is very destructive to metal pipes that are laid underground unless they are coated with asphaltum or some other protective covering.

The solvent action of water increases both with heat and pressure, although heat will sometimes change the character of the water, and thus reduce its solvent action.

Steam is very destructive to lead pipe, but harmless to brass or iron pipe, unless it be mixed with air. Lead and zinc when exposed to water form a coating upon their surfaces, which usually protects them from further corrosion.

Hot water, if it be pure and free from gases or air, will not attack pipes of iron, brass, or lead to an extent sufficient to poison the water or render it unfit for cooking purposes, unless it should be allowed to stand for a few hours before being drawn off.

ABSORPTION OF GASES IN WATER.

833. Several varieties of gas are soluble in water, but in different proportions. Pure water at atmospheric pressure and ordinary temperature absorbs an amount of air equal to 4 per cent. of its own volume; of sulphureted hydrogen 4 per cent., and of carbonic acid gas 100 per cent.

The absorptive capacity is doubled by an increase of 15 pounds in pressure.

The relative volume of gas absorbed is, in all cases, directly as the pressure and inversely as the temperature. Thus, if the pressure be increased, the water will absorb more gas, and if it be heated it will absorb correspondingly less gas.

Water is said to be **saturated** when it has in solution all the gas it can hold.

If water is saturated with gas, and the pressure is reduced or the temperature raised, the capacity of the water to hold the gas is reduced, and some will be liberated.

Thus, if water which is under pressure, and is saturated with air, be allowed to flow from a faucet, it will appear milky, because the air is liberated in great numbers of fine bubbles.

A lower pressure usually exists at the end of a line of piping, or in the vicinity of faucets, while water is flowing from them, than at the street main. This reduction of pressure will, if the water be saturated, liberate more or less gas. If air chambers are properly located they will receive this air or gas, and utilize it to reduce shocks caused by a sudden stoppage of the water.

On low-pressure systems the water is frequently saturated with air, or nearly so; but not often in high-pressure systems, because its absorbing capacity is then very great. This is because the pressure has increased, while the water has in solution only the same quantity of air which it held when it left the reservoir. For example, it was saturated, that is, it carried 4 per cent. of air when it lay in the reservoir, and in flowing into pipes it acquires a pressure of 75 pounds per square inch. Its absorptive capacity is increased to 24 per cent., but it contains only the original 4 per cent. of air; consequently, it will absorb 20 per cent. of its volume of air if it has an opportunity. If water in that condition encounters a supply of air, also under pressure, as in an air chamber, it will soon absorb it and render the chamber useless.

AIR CHAMBERS.

834. Air chambers are used upon lines of pipe to cushion the shocks, which accompany the sudden stoppage, or irregular movements of the water within them. For many purposes they consist merely of a dead end of pipe filled with air, and so arranged that the air will not escape, or be carried away, by the current of water. Air chambers of larger capacity are used upon pumps and hydraulic rams, not only to ease off the shocks of the water column, but to equalize the flow of the water, which would otherwise be intermittent. All natural water carries some air or gas in solution. The air is easily disengaged from the water by change of temperature, by abrupt changes in the direction or rate of flow, and by a decrease in the pressure. Thus, air is liberated at many points in a system of water pipes, in the shape of small globules, or bubbles. These collect at the high points in the system, or in the dead ends of pipe, and they may be utilized by placing the air chamber near the ends of the pipes.

Under high pressures, however, air chambers are nearly useless, because the water will absorb the air from them, as previously explained, but the absorption can be retarded in the larger air chambers attached to pumping machinery by pouring a little olive oil, or other sweet oil, into the chamber. This floats upon the water and forms an air-tight partition between the water and the air. The oil must be renewed at intervals.

Another means of retaining the elasticity of the air chamber is to fill it with soft rubber balls, either hollow or solid. These, however, will be destroyed by hot water.

WATER HAMMER.

835. **Water hammer** is the name given to the shock which is felt in a pipe when the flow of water through it is abruptly stopped. It is very destructive to piping and fixtures, because a shock which is caused at one point is felt throughout the entire line of pipe, and damage is inflicted upon everything connected with it.

The term is also applied to the loud, humming noise frequently made by water pipes when the faucet is opened, and also to the rumbling and snapping noise made by kitchen boilers and hot-water pipes.

The cause of the trouble is quite different in the several cases. In the first case, the movement of the entire column of water from the faucet to the main is suddenly arrested. The water having no elasticity will not compress, and thus momentarily absorb its own momentum; consequently, the momentum of the entire moving column of water must be expended upon the pipes and cocks. If they were sufficiently elastic, the momentum of the water would be absorbed quietly and without noticeable shock, but they are also very inelastic, and a heavy blow results. If the pipes are capable of stretching or yielding, every shock will act to slightly enlarge them. In the course of time the enlargement will result in numerous leaks. If a lead pipe has a thin or weak spot in it, it will swell out and finally burst at that point.

The trouble in the second case is usually due to interference of the currents of water within the pipe, which frequently occurs at the point where a branch is taken off. It is very liable to occur in a long line of pipe of small diameter in which the velocity of flow is higher than it should be.

A very similar sound is caused by the dancing or chattering of a valve upon its seat. The hammering results from the momentary checking and starting of the water column, which is repeated with great rapidity. This action is similar to that of a hydraulic ram, and is very destructive to piping, as before described.

The hammering noise usually heard in a kitchen boiler is due to the formation of steam in the water-back. The bubbles of steam travel towards the boiler until they encounter water that is cool enough to condense them, which is usually at the coupling to the side of the boiler. The condensation is nearly instantaneous, and the volume of the condensed steam or water being only about $\frac{1}{330}$ of that of the live steam, a vacuum is formed. Water rushes into this space

from both directions, and having nothing to cushion the blow the two columns collide with great force. This is most likely to occur when the water in the boiler is heated nearly to the boiling point and the circulation through the water-back is sluggish.

A rumbling noise is sometimes made in the boiler when a hot-water faucet is opened. This is due to the fact that the water is heated up to the steaming point, and as soon as the pressure is reduced, as it is by opening the faucet, steam is instantly liberated in the boiler, or is formed in the water-back.

The *remedy* for water hammer is to use air chambers upon the pipes, which will cushion the shocks, and also to use slow closing faucets, such as compression bibbs.

CONNECTION TO STREET MAINS.

836. Fig. 240 shows two methods of **connecting a galvanized iron service pipe to a cast-iron street main**. The service pipe *A* is connected to the street main *B* by the brass **corporation cock** *C*, forming a straight connection at right angles to the main.

This is a cheap but very dangerous method of connecting, particularly if the ground is of such a nature that the heavy main *B* can settle, as the ends of the cock *C* are liable to be broken off; also, if the service pipe *A* is long and rigid, it will exert strains upon *C* that may ultimately break the connection.

A more reliable connection is that by which the service pipe *D* is joined to the main. A corporation cock *E* is screwed into a hole drilled and tapped in the main in the same manner as *C*. *E* is joined to *D* by means of a lead pipe offset *F* wiped to a brass solder nipple *G* and to a ground coupling and ring, or union, *H*. The lead pipe *F* will easily bend with any change of position due to settlement or change of temperature of *D*.

A *A* or *A A A* lead pipe should be used for this connection, according to the water pressure and the nature of the earth in which it is laid.

A stop-cock, with waste outlet, is placed in the service pipe either at the curb of the sidewalk or just inside the cellar wall; such a cock is generally called a **curb cock** because of its location. Care should be taken to see that the waste outlet will allow the water to escape only from the house side of the cock. In passing a service pipe through a foundation wall, allowance should be made for

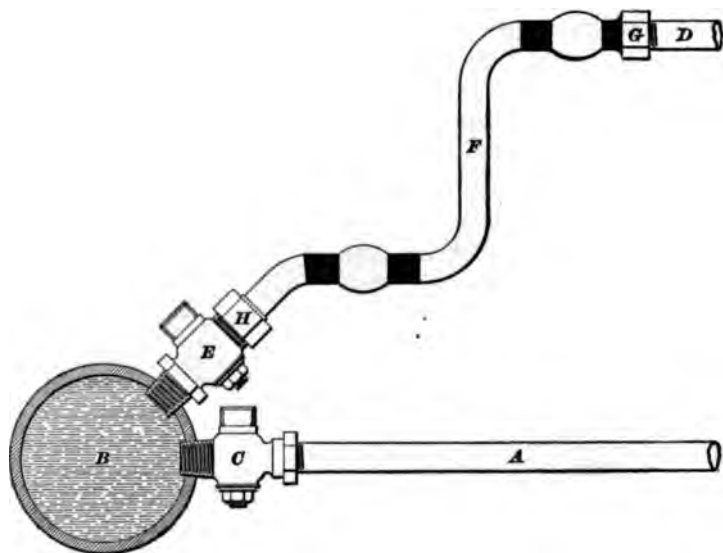


FIG. 240.

probable settlement of the wall, and a space of 1 or 2 inches should be left in the hole above the pipe.

If the stop-cock is located at the curb, it should be enclosed in a tight iron **curb box** having a cover which will keep out surface water, snow, etc., and which is flush with the sidewalk. The service pipe and the stop-cock must be placed far enough underground to escape the action of frost.

837. A **street washer** is simply a branch taken from the water-pipe system for the purpose of furnishing water for washing streets and sidewalks, sprinkling lawns, etc.

The connection is usually taken from the service pipe at a suitable point underground. A stop and waste cock, or valve, is placed on the street washer branch below frost, and is operated by a rod terminating near the surface of the ground, usually within a cast-iron box with a hinged cover.

The orifice of discharge is provided with a hose nipple, and the pipe between the hose nipple and the shut-off cock is drained to a point below frost when the cock is closed.

Pipes which are inside of a dwelling should not be concealed, but should be so located that they can be gotten at readily without injuring plaster or woodwork. Care should be taken to make them clean, and have them present a good appearance.

Piping of all kinds should be grouped together as much as practicable, and should not be straggled anywhere and everywhere, all over the premises.

If pipes run over valuable ceilings, etc., they should have a pan or safe of lead, copper, or zinc under them, which should extend over the whole length of the section where a leak could make any serious damage. This pan should be inclined so as to drain readily, and should discharge at a point where it will be quickly noticed.

838. Hot-water connections may be made of lead, brass, copper, or galvanized iron. Black iron is unsuitable. The choice will depend upon the pressure and upon the appearance desired; also upon the character of the water and its action upon the metal. In all cases where the water corrodes the metals named, pipes must be used which have an interior coating of glass or porcelain or are lined with pure block tin.

Brass tubing has the following advantages: It will not corrode to any appreciable extent in pure water, and it will not sag in consequence of heat, as lead will.

To secure easy curves and to avoid a multiplicity of sharp turns resulting from the use of elbows, T's, or other iron pipe fittings in a building, the iron supply pipes may

be continued to the fixtures with lead pipe which can be easily bent to fit any condition.

In cases where it is known that the water will not corrode either lead or brass, the cold water may be conducted through lead pipe and the hot water through brass.

Ale, beer, and other liquors should be conveyed in block-tin or tin-lined pipes.

NOTCHING FLOOR-BEAMS.

839. When it is necessary to run a pipe under the flooring, it should be run parallel with the floor-beams if possible. If that can not be done, then notches must be cut across the beams of sufficient depth to admit the pipe. The notch should be made near the end of the beam, and should never be made at, or anywhere near, the middle of the beam. The strength of a floor-beam is not in direct proportion to its depth, but varies with the square of the depth. Thus, a beam 10" deep is four times as strong as a beam 5" deep, of the same thickness.

For example, in Fig. 241 the strength of a certain beam 10" deep, loaded at the middle, without the notch, is 100

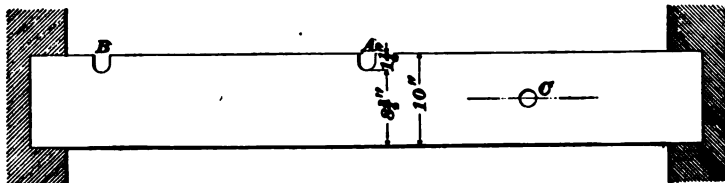


FIG. 241.

pounds. When a notch $1\frac{1}{4}$ " deep is cut in the middle of the beam, as at *A*, the depth is reduced to $8\frac{3}{4}$ ", and the strength is reduced in proportion to the square of the depth, or to $76\frac{1}{2}$ pounds, a loss of $23\frac{1}{2}$ per cent. of the total strength. The same notch may be cut near the end, as at *B*, with a very slight loss of strength, unless some very heavy weight rests upon the beam close to it. A hole of the same diameter may be bored through anywhere along the center line of the beam, as at *C*, without perceptible loss of strength,

provided that the diameter of the hole does not exceed about one-seventh the depth of the beam.

While the notching of floor-beams in the middle may not always weaken them to such an extent as to make them unsafe, yet it is almost certain to impair the stiffness of the floor to a serious degree, and often spoils it.

SAGS IN PIPES.

840. The effect of the sagging of a lead pipe between its supports, as at *B* in Fig. 242, is that air will collect in the high parts of the bends, and will form **air locks**.



FIG. 242.

These greatly impede the flow of water through the pipe. If the pressure of the water is small and the sags are numerous, they may stop the flow entirely. Thus, a sink waste pipe in that condition might refuse to pass water, and would appear to be clogged by refuse, although the trouble was wholly due to air locks.

If air has accumulated in the top bends *A* and *C*, the water will rise on one side of the bend and will slightly compress the air which is entrapped at that point. The air will depress the water on the other side of the bend, raising its surface at the next upper bend. The difference in level between the surfaces of the water on the opposite sides of a bend is the measure of the resistance which the air in that bend offers to the passage of water. Thus, if the difference of level at *x* equals 1 inch at each sag, and the sags are 30 in number, the total resistance to the flow of water would equal a reduction of driving pressure, or head, of 30 inches. If the actual head of water is less than 30 inches, no water will pass, because the water will not rise high enough at any bend to pass over it. If the head is a little

more than 30 inches, the water will "creep over" from one sag to the next, and will flow slowly from the end of the pipe. If the head is high and the outlet is opened wide, the rush of water will usually carry the air along with it and so clear the pipe.

In leading water from tanks, or under low pressure, this defect should be carefully avoided. Thus, if two tanks situated on the same level were connected by a pipe such as described, the water in the receiving tank would stand 30 inches lower than it would if the sags were entirely removed from the pipe.

841. A practical illustration of "air lock" in a plumbing system as it applies to tanks or other vessels depending upon one another for their supply, is shown in Fig. 243.

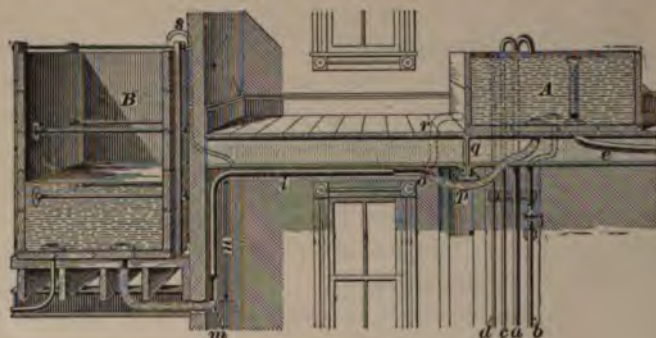


FIG. 243.

The tank *A*, we will assume, supplies water to the plumbing fixtures in a building. It is filled with water by a pump, through the delivery pipe *a*, and is connected up complete with a cold-water distributing pipe *b*, expansion pipe *c*, tell-tale *d*, and standing waste overflow *e*. Extensions are then made to the building and more plumbing installed. The tank *A* is now too small to store the proper amount of water to supply the entire building for a reasonable length of time without comparatively frequent refilling, so an extension is made to *A* in the form of another tank *B*. This second tank is set at such a height that its top is level with

the top of *A*, and it is supplied with water by a communication pipe *i* which joins the bottom of each tank as shown.

This is done to overcome installing a separate delivery pipe, a tell-tale pipe, and an overflow pipe for the tank *B*, the supposition being that when *A* is filled by the pump, the tank *B* will also fill up, and this it certainly will do if air does not become locked in the pipe *i*.

As the tanks are connected, however, air will become locked as shown, and the loss of head in *B* will equal the vertical height of the air column as represented by the distance *n*.

From what has already been said regarding the formation of air locks, the reader will see at a glance that the pipe *i* will be air-locked between the points *m* and *o*, the cause of the lock being the pocket *p*, made in order to clear the lower flange of a steel beam *q*.

There are several ways by which this air lock may be avoided; that is, by which air in the pipe may freely escape to the atmosphere, and the pipe *i*, consequently, permitted to fill with water.

One method is to make a connection to the side of the tank *A*, as shown by dotted lines at *r*, instead of to the bottom. Another method is to leave the bottom connection as it is, and run in a small **air relief pipe** *s*, the upper end of which is bent over the tank and the lower end joined to the highest point of the air-bound part of *i*, as shown by dotted lines.

Either of these simple changes will effect a permanent remedy, and the water line in *A* will always be level with that in *B* when no water is being drawn from either of the tanks.

Where there is a liability of forming air locks by the gradual accumulation of air in a pipe, a blow-off cock should be attached at the lowest point on the line. By opening this cock and starting a strong current of water, the collections of air may be blown out; or small pet cocks may be attached at the top of a bend where air is likely to accumulate.

Another bad effect of sags in pipes is that the pipes can not be entirely emptied of water. Each sag will retain a quantity. If the pipes be exposed to freezing weather, these pockets of water will freeze and burst the pipes, although they appear to be empty.

CIRCULATION OF WATER.

842. If water be heated, it expands in bulk; thus, a cubic foot of hot water weighs less than a cubic foot of cold water. Circulation is caused solely by the change of weight

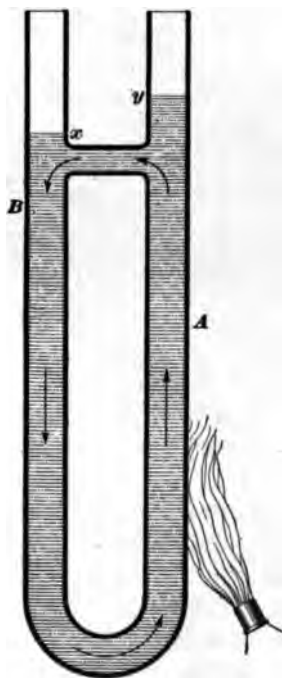


FIG. 244.



FIG. 245.

due to expansion by heat and contraction by cooling. For example, suppose two vertical tubes are connected at the bottom as shown in Fig. 244. If the water in *A* is heated, it still weighs the same as before, but it occupies more

space; consequently, the surface of the water rises in the tube from the original level x to a new level y . Now, a difference exists in the height of the two columns, but they weigh the same, and balance each other. If a connection be made near the level x , the extra head in A will cause the water to flow over into B . The head which compels this flow is equal to the difference between the levels x and y . The pressure thus generated is small, but it is enough to overcome the friction of the water among its own particles and against the surface of the tubes, causing it to flow over into B . Weight is thus transferred from A to B , A becoming a little lighter and B a little heavier. The two columns of water no longer balance; B sinks, and A is forced to rise. The cool water from B passes over into the foot of A and encounters the heat. It is expanded, its weight is diminished, and it is crowded upwards by the cooler and heavier water coming in behind it. Some of the heat will be lost by radiation, but the mechanical effect of the remainder of the heat will be spent in overcoming friction of the water. The rapidity of circulation will depend upon the difference in temperature; that is, the difference in weight of the two columns A and B , their vertical height and the resistance due to friction, change of direction, etc.

If, instead of two tubes, as shown, a single tube A , Fig. 245, of capacity equal to the two, and having a partition B , which divides it into two parts, be used, it will operate the same as before. But if the partition be removed, the upward and downward currents will mingle and interfere, thus causing much more friction, and retarding the circulation. The circulation would be very slow and uncertain if the tube were small in diameter.

If the divided tube above referred to were laid in a horizontal position, so that it was divided into an upper and lower chamber, the circulation would still take place, but at a much slower rate. If no partition were present, the circulation would be very slow and imperfect. The circulation of water in vertical and horizontal boilers is illustrated in Figs. 249, 250, and 251.

843. The rapidity of the circulation within a horizontal boiler may be increased, when necessary, by dividing it into an upper and lower chamber by means of a horizontal partition *A*, as in Fig. 246.

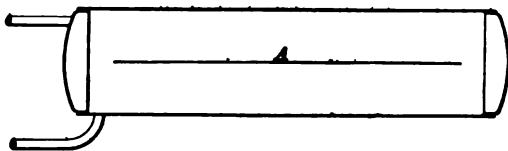


FIG. 246.

The circulation of water in a system of hot-water pipes employing a return pipe, as shown in Fig. 249, is quite rapid because of the great difference in temperature of the water in the rising and return pipes.

The matter of friction must be carefully attended to; all sharp bends and contractions in the pipes must be avoided. Abrupt enlargements of the pipe, or pockets, create friction and impede the flow.

The circulation in a system of pipes which is used for cooling purposes depends upon the same conditions. The ice or refrigerating liquid should be applied near the top of the descending column; the material which is to be cooled should be allowed to touch only the ascending column, and, if possible, placed at its base. In this way the greatest possible difference in density of the ascending and descending columns will be obtained.

Water must be heated from below and be cooled from above. It conducts heat so slowly that the heating or cooling depends very largely upon circulation. A liquid which conducts heat readily, like mercury, can be heated from any direction.

If water is to be heated in a tank, the heating pipes should be placed a few inches above the bottom; if it is to be cooled, the cooling pipes should be placed just below the surface of the liquid.

844. The **boiling point of water** varies with the pressure. The temperature at which the formation of

steam begins does not increase in the same ratio as the pressure. Thus, water boils, under atmospheric pressure only, at 212° ; under 10 pounds gauge pressure, at 238° , which is an increase of 26° temperature for 10 pounds increase of pressure. From 50 to 60 pounds pressure the temperature rises from 297° to 307° , or about 1° for each pound of pressure. From 100 to 110 pounds pressure the temperature rises from 337° to 344° , or about 7° for each 10 pounds of pressure.

In the table of Properties of Steam will be found the boiling point of water (that is, the temperature of steam) under varying absolute pressures above and below atmospheric pressure; also, the volume of steam at that pressure compared to the volume of water of which it is composed.

Water or steam can not be heated to a higher temperature, under a given pressure, than that named in the table. If the temperature be increased, the pressure will be increased, inevitably. Water can not be *superheated*. The relation between temperature and pressure is absolute. The temperatures of water and of the steam which is in contact with it are always equal. The water, however, may vary several degrees in temperature in various parts of a boiler, owing to the loss of heat by radiation or cooling. These local differences of temperature give rise to currents in the water, and circulation will take place.

845. It has been stated that water expands by application of heat; further particulars on this point are given in the table of Expansion and Weight of Water. With the aid of this table, the student will be able to compute the weight of any volume of water having any temperature between 32° and 390° F.

846. The expansion given in the table is, of course, cubical, but since water must always be confined in a vessel, the increase in volume due to increase in temperature will travel up the vessel; consequently, it is practically linear expansion.

The **expansion of water** may be found by reference to the before-mentioned table, assuming that the volume is 1 at 32° F.

To compute the change of volume due to change of temperature:

Rule.—*Divide the product of the original volume and the comparative volume at final temperature by the comparative volume at original temperature.*

EXAMPLE.—A vessel containing 40 gallons of water is raised in temperature from 62° F. to 200° F. What is its final volume?

SOLUTION.—Original volume = $40 \times 231 = 9,240$ cu. in.

$$\text{Final volume} = \frac{9,240 \times 1.03889}{1.00101} = 9,589.65 \text{ cu. in.} \quad \text{Ans.}$$

Consequently, amount of expansion = $9,589.65 - 9,240 = 349.65$ cu. in.

If this be divided by the sectional area of the vessel in which the water expands, the quotient will be the height to which the water will rise.

EXPANSION PIPES.

847. An expansion pipe is a pipe open at the top which extends upwards from a kitchen boiler to a tank at a higher elevation and empties over it, or delivers at some other suitable point. (See Fig. 243.) The pressure within the boiler is determined by the height of the surface of the water in the tank above it, and the boiling point of the water will correspond to that pressure, as given in the table of Properties of Steam. The boiling point, therefore, will be above 212° in all cases. If steam is formed in the boiler, it may force some of the water back up into the tank. But the expansion pipe being connected at the top of the boiler allows the bubbles of steam to pass upwards through it and thus escape. The water will at all times be warmer in the expansion pipe, providing circulation is obtained through it, than in the supply pipe from the tank to the boiler; consequently, the level of the water standing

in the expansion pipe will be a little higher than the surface of the water in the tank. Advantage may be taken of these circumstances to keep the temperature of the water in the boiler below its boiling point. For example, the water when heated to the desired temperature will stand several inches higher in the expansion pipe than in the tank, as explained in Art. 842. The end of the expansion pipe is carefully adjusted to that level, so that if any increase in temperature occurs, the consequent expansion will cause the water to overflow into the tank or elsewhere. The weight of the column of hot water will no longer balance the cold-water supply column, and cold water will come down into the boiler and displace the hot water, driving it up the expansion pipe until the temperature falls to a point where the columns will balance.

Thus, the maximum temperature of the water may be kept at a desirable degree, regardless of the pressure, and the formation of steam within the boiler may be prevented, so long as the cold-water supply is maintained.

The expansion pipe will serve as a *relief pipe* and as a *heat regulator*, when it is used in connection with a pressure-reducing valve upon a system which is supplied by a high-pressure street main. In that case the expansion pipe overflows into a sink or any convenient point, and the excess of water which thus overflows is wasted. The volume of the boiler and expansion pipe being constant, it follows that the pressure put on by the reducing valve will exactly balance the column of hot water contained in the expansion pipe only when its density and temperature are at a certain degree. If that temperature is exceeded, the weight of the column diminishes, and the cold water will force its way inwards until the temperature is diminished to the proper point and the balance is restored.

Open expansion pipes are seldom applied to a system of plumbing supplied by street pressure. In most cases expansion is permitted to travel back into the street mains. When a check-valve, such as a pressure-reducing valve, is

attached to the main service pipe, the surplus water due to expansion escapes through a safety valve provided for the purpose.

WATER-BACKS, OR WATER HEATERS.

848. Hot water for domestic purposes is commonly heated in the cooking range by means of a *water-back*, or by a coil of pipe which extends around the top edge of the fire-box.

A **water-back** is a cast-iron block which is provided with internal passages through which water can flow. It is made by coring out the interior at the time of casting, or by casting the block around a flat coil or loop of wrought-iron pipe, which is laid in the mold. Water-backs cover one side of the fire-box, and are usually tapped with two holes for 1-inch wrought-iron pipe.

A water-back is, properly speaking, a *water heater*. It is generally called a "water-back," but there are many places in the United States where its name changes with its position in the fire-box of the range. For example, when the water heater is located at the side or front of the range, it is known as a **water-front**.

One of these heaters is shown in section in Fig. 247. The casting *a* is the heater proper. Its flat sides are tied together by a partition *b* which also serves to compel the water to circulate

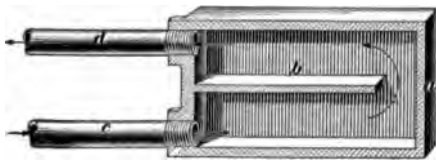


FIG. 247.

throughout the entire length of the casting.

The pipe *c* supplies the heater with cold water, usually taken from the bottom of the kitchen boiler; this pipe is called the *return pipe to water-back*. The pipe *d* receives hot water from the heater and delivers it to the boiler, where it is stored and ready for use.

A water-back, having water inside and fire outside, is exposed to severe internal strains, and the metal must be much thicker than is required to resist the water pressure.

Water-backs are designed to resist a pressure, when cold, of 700 pounds per square inch. The manner of connecting them to a boiler is clearly shown in Figs. 249, 250, and 251.

849. A **fire-box coil** for heating water, instead of a water-back, is shown in Fig. 248. The coil is usually made of copper tube, $\frac{3}{4}$ inch internal diameter and about $\frac{1}{8}$ inch thick, placed on the inner edge of the firebricks, as shown.

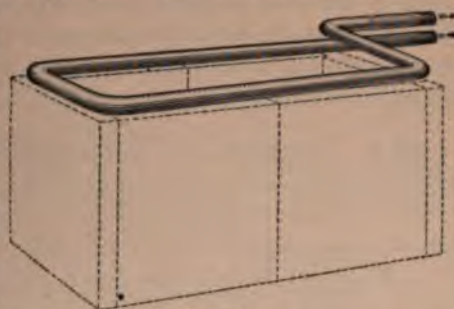


FIG. 248.

Water-backs are sometimes overheated and weakened, or are eaten away by internal corrosion, and if an extraordinary pressure is brought to bear within them, they will explode with disastrous effect. The damage which results from the explosion of a water-back greatly exceeds that from the bursting of a pipe coil, because of the greater interior area and greater volume of contents.

850. The **size of a water heater** is measured by its heating surface in square inches, reckoning only that side which is exposed to the fire. About 100 square inches of external heating surface are sufficient for a 40-gallon boiler where water is plenty, or a 50-gallon boiler where water is scarce.

The quantity of water heated, the time required to heat it, and the quantity of water consumed, vary in every case. The size of a water-back which should be placed in a range depends upon the plumber's judgment. A large boiler requires a large water-back, and a small boiler a small one. A large boiler and a small water-back means scarcity of hot water or plenty of lukewarm water. A large water-back and a small boiler means boiling hot water, and rumbling, snapping, and cracking noises, caused by the formation of steam.

HOT-WATER BOILERS.

851. **Boilers** for domestic use are made either of *copper*, thoroughly *tinned* upon the inside, or of *galvanized iron*. They are usually set in a vertical position, but when circumstances require it they can be operated horizontally. Boilers are also made *double*, one within another, to suit places where the water is drawn from two sources at different pressures, and where one water heater must heat the water in both boilers.

852. The **size of a boiler** which should be placed in a residence is a matter of great uncertainty. Experience shows, however, that a 40-gallon boiler is usually sufficient for a house having one bath-room and one sink, a set of wash-tubs and a wash-bowl. If there are two bath-rooms, a 50 or 60-gallon boiler should be used. It is good policy to have the boiler a little larger than necessary, rather than small, particularly if the pressure is low.

Boilers may be covered with neat wooden lagging, composed of strips of pine or hard wood, $1\frac{1}{2}$ inches to 2 inches wide, $\frac{3}{4}$ inch or more in thickness, tongued and grooved, and confined by brass or galvanized iron bands. This will prevent the excessive waste of heat which occurs from radiation, and which tends to make the kitchen uncomfortably warm.

Safety valves are not necessary when the boiler is directly connected, without the intervention of a check-valve or a reducing valve, to the street mains, or to a tank, because the expansion of the water in the boiler is relieved by forcing a small amount back into the supply pipe. Where that method of relief is prevented by check-valves or other devices, *safety valves must be used*.

A vacuum valve must be attached if the boiler is liable to be emptied and to have a vacuum formed within it, because the pressure of the atmosphere upon the outside will crush it, unless the vacuum be destroyed. A boiler which is supplied with an expansion pipe does not require either a safety or vacuum valve.

Boilers should be tested by hot-water pressure to 150 pounds per square inch for general service. A test of 100 pounds per square inch is enough for working pressures of 30 pounds or less. For extra heavy working pressures, the boilers should be tested to double the working pressure, or to at least 100 pounds more than the working pressure.

The consequences of the explosion of kitchen boilers are likely to be very serious, and the plumber should insist that the manufacturer test every boiler to a proper test pressure, and guarantee it to endure that pressure.

Iron boilers are galvanized after they are riveted together. The interior can be examined by pushing a lighted candle inside and looking through the pipe holes.

Boilers which are constructed with a single line of rivets in the longitudinal seam, are called **single-riveted**, and are suitable for moderate pressures only. Those having two lines of rivets in zigzag or alternate order are called **double-riveted**, and are suitable for heavy pressure. A single row of rivets is sufficient to secure the head or the bottom.

853. The proper mode of connecting up vertical boilers is shown in Fig. 249. The cold-water pipe *X* should enter at the top of the boiler and end at the line *ab*, which should be about three inches above the level of the water-back *W. B.* When the pressure is shut off, the water is likely to be drawn out of the boiler by the opening of a faucet at a lower level, as at *C*. The pipe *X*, then acts as a siphon, and will run the

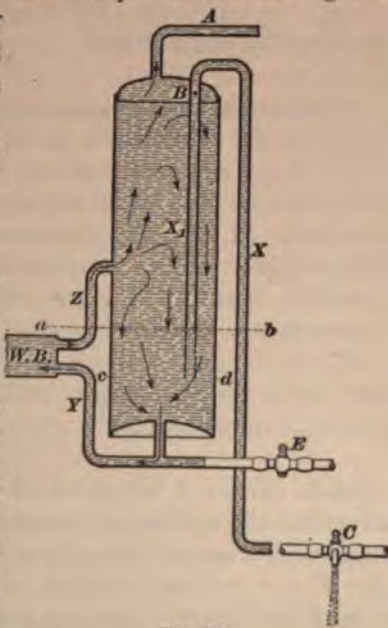


FIG. 249.

water out until its level falls to the end of the pipe X_1 . If X_1 extends to the line $c d$, the water-back will be drained, which is dangerous. Unless the fire is drawn, the water-back will become overheated, and when the cold water is turned on, the water-back will be very liable to crack or explode. All danger from siphoning can be avoided by drilling a small hole (about $\frac{1}{8}$ inch) in the pipe, as at B . The hot-water pipe A is connected at the extreme top of the boiler.

The general direction of the circulation is shown by the arrows. Connections are made to the water-back by two pipes Y and Z . The pipe Y should be connected to the bottom of the boiler, and should be inclined upwards towards the water-back. The pipe Z receives the hot water from the water-back, and should be inclined upwards towards the boiler. It should be connected to the boiler at a point not less than $\frac{1}{3}$ the height above the bottom, and it should be at least 1 inch internal diameter for a 40 to 60-gallon boiler.

A **blow-off, or sediment cock**, to remove mud and sediment, should be provided, as at E . This may empty into a sink, or may be connected to a waste pipe on the house side of the trap seal. In all cases, however, it is best to blow the boiler off into the open atmosphere. If possible, the sediment blow-off connections should never be made in such a manner that boiler water may leak away without being observed.

Boilers connected in this way require considerable time to heat their entire contents so that hot water will readily appear at the faucets.

854. When it is desired to get hot water without delay after starting up the fire, another system of hot-water connections is resorted to. This is shown in Fig. 250. The pipe Z is connected directly to the hot-water distributing pipe A , as shown. Thus, the hot water as it comes from the water-back can flow direct to the fixtures, or if none is wanted it can flow into the boiler.

When hot water stands in the pipes for any considerable time it cools off, and it sometimes happens that several gallons of cold or lukewarm water must be drawn from the faucet before hot water appears. This is always annoying, and when water is scarce, it is very troublesome and sometimes expensive. To secure hot water at each fixture promptly upon the opening of the faucet, a *return pipe* must be used. This pipe is joined to the hot-water supply pipe near each fixture, and it should always be one or two sizes smaller than the hot supply pipe. The *return branches* are united to a descending pipe, which enters the boiler at *B*, Fig. 250, about one-third up. It is not good practice to connect the return pipe to the extension of pipe *Y* as shown by the dotted lines, because cold water from the bottom of the boiler will surely flow up this pipe and mix with the hot water in the hot-water supply pipe before it reaches the faucet.

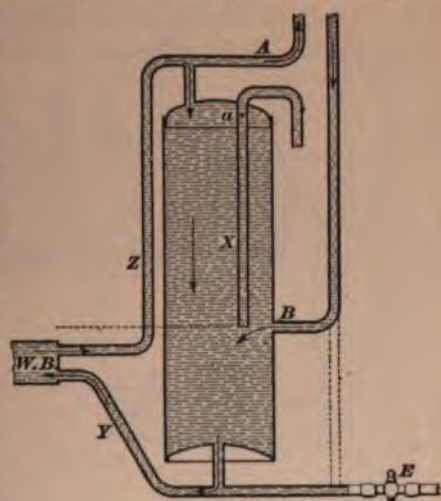


FIG. 250.

Ordinary check-valves should not be employed in the return pipe, because the circulating current is too weak to operate them.

The hot water rises in *A* and returns in *B*, maintaining a circulation which is sufficient to keep *A* filled throughout its entire length with hot water of satisfactory temperature.

855. Horizontal boilers are employed where there is no room to stand a vertical boiler. The manner of connecting them is shown in Fig. 251. *A* is the hot-water

supply pipe; *B* is the return pipe; *X* is the cold-water supply; *Y* and *Z* are the connections to the water-back *C*. The water-back should be at a lower level than the bottom of the boiler. The arrows show the direction of the circu-

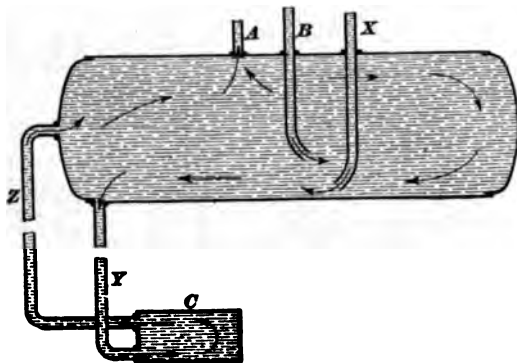


FIG. 251.

lation. The boiler may be supported upon brackets or may be suspended by bands from overhead floor-beams.

Horizontal boilers are usually suspended immediately over the kitchen ranges.

856. Double boilers are used to heat water which is supplied from two separate sources; usually one part of the boiler receives water from street mains, and the other is supplied from a tank. The two boilers are combined in one structure, as shown in Fig. 252. The cylinder *B*, or **inner boiler**, which is fed from the tank and sustains the highest pressure, is placed inside of the low-pressure boiler *A*. The inner boiler is heated by the water in the outer one; thus both are operated with one water-back, or heater.

If the inner boiler should ever be emptied while the outer one was full, it might collapse in consequence of the external pressure; therefore, care must be taken to empty the outer boiler first at all times. *B* should always be filled first. The connections to each boiler are made in the same manner as for an ordinary vertical boiler. *C* and

D are the pipes to the water-back. *E* is the hot-water supply pipe to the lower stories, or *street pressure system*; *F* is the hot-water supply to the upper stories, or *tank pressure system*. *H* is the cold-water supply from the street mains and *G* is the cold-water supply from the tank. *L* is a blow-off or sediment cock for the inner boiler, and *M* is a similar cock for the outer boiler. It should be noted that the inner boiler can not be emptied without opening both *L* and *M*, and thus emptying both at the same time. The inner boiler should be of copper, and should be thoroughly tinned both inside and out.

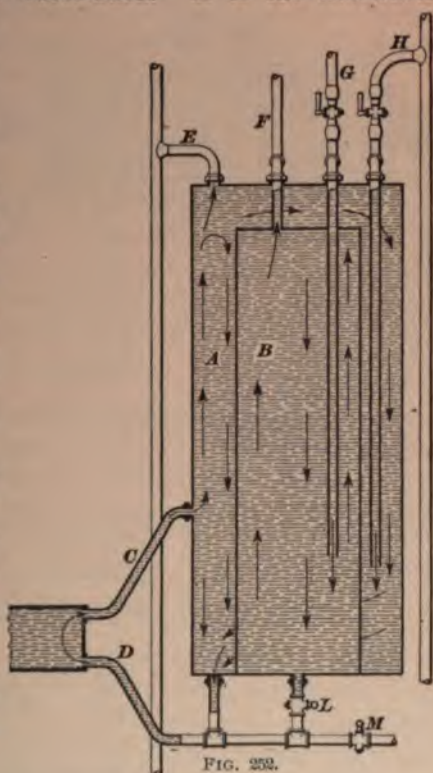


FIG. 253.

BOILERS HEATED BY STEAM.

857. The hot-water supply for large buildings, hotels, etc., is sometimes heated by steam, as shown in Fig. 253. A horizontal boiler *A* is shown, but a vertical one can be used equally well. The steam is taken in at the valve *C*, and after passing through the coil of brass or copper pipe *D*, it passes off in the form of water through the pipe *E* to the steam trap. The coil should be inclined so that the steam which is condensed within the tubes will flow by gravity towards the exit *E*. *B* is the cold-water supply pipe; *F* is the hot-water supply to the fixtures, and *G* is the return pipe from the fixtures.

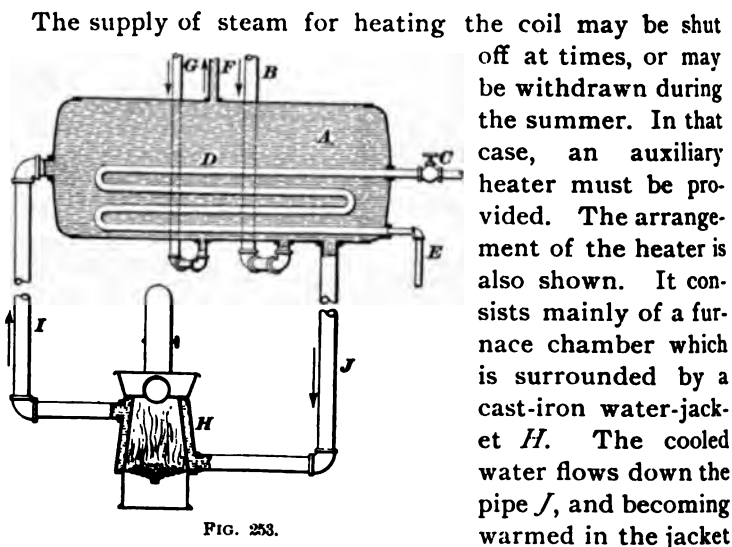


FIG. 253.

H, flows upwards through the pipe *I*, thus maintaining a constant circulation.

STORAGE TANKS FOR WATER.

858. If water is to be stored in a tank for drinking and cooking purposes, great care must be taken to make the tank lining of a material that will be insoluble in the class of water contained. It is found that sheet copper tinned on the inside forms an excellent lining, and is often used in wooden tanks.

Tanks made of impervious materials, such as porcelain, glass, slate, stoneware, etc., are also used for storing drinking water. The slabs of which the tank is composed are usually made water-tight at the seams with red or white lead, and are held in position by staybolts which bind the opposite sides and resist the water pressure.

A sheet-metal tray, or **safe**, is usually placed under water tanks in buildings to prevent damage by leakage or overflow.

The safe is usually turned up 3 or 4 inches all around its edges, and is provided with a $1\frac{1}{4}$ or $1\frac{1}{2}$ -inch **safe waste pipe**

discharging to the atmosphere at some convenient point, such as over and into a sink.

Sheet lead, zinc, and galvanized iron are unsuitable for tank linings, because they will poison the water.

Tanks may be constructed of plain black sheet or tank iron, or of cast iron. These will not injure the water unless it stands a long time, in which case it will be discolored, and will acquire a nauseous taste.

If rain-water or other soft water is to be stored in a lead-lined tank, the lining should first be thoroughly covered with a coat of lime wash. This will form a coating of carbonate of lead, which will retard the corrosion of the lead and the contamination of the water.

859. Circular wooden tanks, made of well-jointed staves, thoroughly hooped, are used for storing drinking water, whenever circumstances will permit. **Cedar** is commonly used in their construction, since it is easily made water-tight and is very durable.

Wooden tanks are chiefly used for out-of-door purposes, being often placed above the roofs of the buildings they are intended to supply.

Tanks of extra large capacity are frequently made of wrought-iron plate, and are circular in form. They may be rectangular in form if desired, but for equal capacity rectangular tanks are more expensive, because of the elaborate system of bracing which is required to keep them in proper shape.

Iron tanks require protection against frost; for, since iron is a good conductor of heat, the heat of the water is rapidly transmitted to the outer air, and the water contained in the tank freezes. This does not occur to such an extent in wooden tanks.

860. Since plumbers are expected not only to line tanks with sheet metal, and thereby make them water-tight, but also to design them and oversee their construction, we will treat rather extensively upon the design and construction of **rectangular wooden tanks**, this form being generally employed inside buildings.

Rectangular wooden tanks are very difficult to keep water-tight; consequently, they are usually lined with sheet metal. In a lined tank, the wooden sides and bottom have only to support the sheet-metal lining and resist the hydrostatic pressure. They are not required to be water-tight.

The sides and bottom should be $1\frac{1}{2}$ inches thick and upwards, according to the distance between the supports and the depth of the tank. The supports should be placed so closely together along the sides and ends, and across the bottom, that the planking will not spring between them.

In Fig. 254 is shown two methods of bracing the sides of a rectangular tank. The sides are prevented from bulging

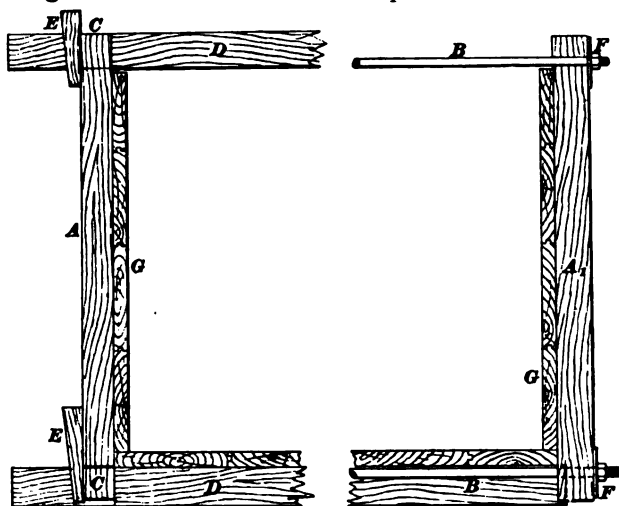


FIG. 254.

outwards by vertical posts A and A_1 . In the method to the left of the figure the posts A are secured in position by mortise and tenon joints C to the horizontal timbers D, D , and are wedged tight by wooden wedges E, E . This class of bracing is not so strong as that which ties the post A_1 , which is held in position at top and bottom by wrought-iron bolts or rods B, B . The lower rod should be stronger than the top rod.

All the bracing timbers must run crosswise with the planking G and fish-plates, or large iron washers F should

be used to prevent the nuts from "chewing" into the wood.

The ends of the tank must be supported by posts and tie-rods, as the sides are. The bottom tie-rods will necessarily pass through the sills. The sills must never be notched to pass the rods, but holes for that purpose should be bored along the center line of the timber, making the holes $\frac{1}{4}$ inch larger than the rods, for convenience in pushing them through. It should be remembered that the pressure upon the sides of a tank depends wholly upon the *depth* of the water, and is unaffected by the width of the tank, while the pressure upon the bottom depends upon its area and the depth of the water. Thus, with an equal depth of water, a tank but one inch wide or less will have exactly the same bursting pressure upon its sides as one 10 feet wide or more.

861. When a wooden house tank is filled with water, it tends to bulge outwards, and when it is emptied it returns nearly to its original shape. There is usually more injury done to lead tank linings by the opening and closing of angles and sharp curves when the sides and ends of the tank yield under the pressure, than is accomplished by corrosion. This is due to the fact that the elasticity of lead is exceedingly low, and, consequently, lead can not successfully withstand repeated bending at the same point.

Fig. 255 shows a section of a wiped seam in the bottom angle of a lead tank lining. It clearly illustrates how lead lining in a poorly made tank will not remain long watertight unless a constantly uniform water level is maintained. The view is supposed to be about the middle of the tank, because this is the place where the side *a*, if unsupported, will spread out most.

When the tank was made, the lowest side plank *a* was spiked closely against the bottom plank *b*, and, of course, the lining was put in to fit snugly into the angles, then wiped in position.

As the tank filled with water, the pressure upon the side became too great for the spikes to resist; hence, they were

drawn out to the extent shown, and the plank *a* bulged outwards about $\frac{1}{4}$ of an inch. The lead lining, however, fitted snugly against the woodwork, and offsets are now formed



FIG. 255.

along the edges of the solder *c*, as shown at *d* and *e*, which weakens the metal at those points. Notwithstanding this defect, the lining would last a reasonable length of time if the offsets in the metal did not change their shape.

If, however, the side *a* springs back to its original form when the tank is emptied, or should the lining change much in temperature, and thereby cause the offsets to compensate for the expansion and contraction of the sheets, the metal along the edge of the wiping will soon become "rotten," and to a certain extent brittle, a crack being formed along the edges of the wiping.

To avoid this trouble, then, the sides of the tank, particularly at the angles, should be made strong enough to resist the hydrostatic pressure, without any perceptible bulge or opening of the joints. Fig. 256 shows how this is accomplished in small tanks which require to be neatly made and strongly built, such, for example, as **tanks exposed to view** in a building and whose sizes do not exceed 4 ft. $\times$ 3 ft. $\times$ 2 ft. deep. The sides *a, a* and ends *b, b* are

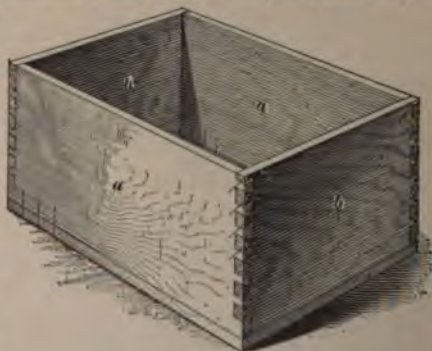


FIG. 256.

joined together at their corners by **dovetailed joints**, which are reenforced by nails, shown by dotted lines. The sides and ends are then carefully "squared" and the bottom is spiked on, the nails also being shown by dotted lines. These nails or spikes prevent the lower parts of the sides and ends from spreading, and, consequently, preserve the lining.

Should the tank be much larger or much deeper than the above dimensions, it will be necessary to brace its sides and ends against bulging, in order to avoid the use of too heavy planking.

862. Fig. 257 shows what plumbers would call a **large open house tank**; its dimensions, we will suppose, are 8 feet long, 5 feet wide, and 4 feet deep. The planking is white pine 2 inches thick and free from knots. The plank-

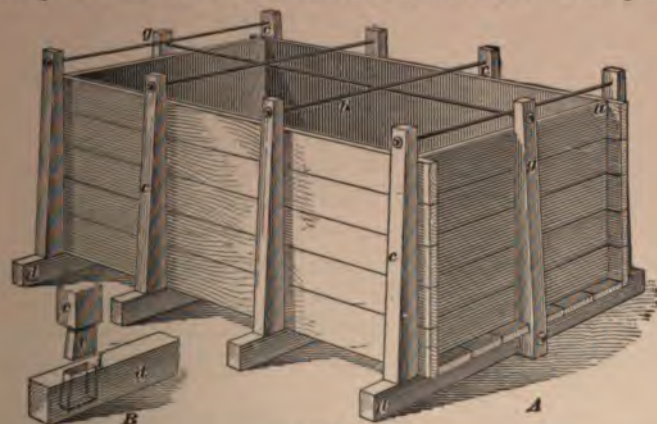


FIG. 257.

ing of the ends is "let in" the side planking about $\frac{1}{2}$ of an inch, as shown at *a*, and the sides are drawn together by iron tie-rods *b*, and braces, side posts, or stiffeners *c*, the lower ends of which are secured by "mortise and tenon" joints into the timbers *d*, *d*, etc., which also support the bottom planking of the tank.

A detail drawing of the mortise and tenon joint which connects *c* to *d* is shown at *B* in the same figure. The tenon *e* is slightly splayed upon the outside face to fit a

corresponding splay or bevel shown by dotted lines in mortise *i*. The chief advantage of this form of a tenon is that the greater the pressure against the braces, the more firm will the connection become; the tenons can not be drawn from the mortise holes if the tank sides are made a tight and snug fit. The most common method, however, of joining the vertical posts to the horizontal timbers which tie their bases together, is to have the faces of the tenon parallel and the outer end of the mortise slightly beveled so that a wedge may be employed to press the posts hard against the tank sides, as shown at *c* in Fig. 254. Particular care must be taken to allow enough of the timber to project beyond the mortise hole to form a good, unyielding abutment for the tenon or the wedge, as the case may be. The length shown in Fig. 257 will take as much force as the tenon can impart to it, and the proportions shown are about correct. If the ends of *d* are cut off too short, the tenon will shear off the block of wood which resists it, and thus the sides of the tank will spread. The ends of the tank in Fig. 257 are 5 feet long by 4 feet deep, and although a brace is not absolutely necessary to prevent the tank from bulging at these points, still it is better to use one at each end, as shown at *g, g*, so that the ends, like the sides, will be practically unyielding. These braces are drawn together by iron tie-rods above and below the tank, the lower rod running through holes bored in the neutral axis, or middle of the timbers *d, d*.

Should the tank be over 5 feet deep, it becomes necessary to tie the braces together at suitable points in their length, so as to avoid the use of too heavy braces. This is accomplished by running a tie-rod entirely through the tank, and protecting it from the action of the water by a slip tube, which is wiped to the tank lining.

Lead forms an excellent lining for tanks which store what we call "hard water," or that which contains sulphates or carbonates, because a thin insoluble crust of sulphate or carbonate is formed on the inner surface of the lead, and this protects the lead from any action with the water.

If a tank is to be employed for storing soft water, such as rain-water, or even mineral or spring waters containing certain salts, such as nitrates and chlorides, the water will have a dissolving influence upon the lead, and is, therefore, subject to contamination. If water contains much free carbonic acid gas, it should not be brought into contact with lead, as the carbonate dissolves in water containing this substance.

Sheet copper, well and heavily tinned on its inside surface, is found to be very well adapted for lining tanks to contain soft waters. Of course, a block-tin coating is not insoluble in all waters, and while it gives excellent results with some waters, it may be just as soluble as lead or zinc in others. The results obtained by the use of tinned copper for soft-water tanks are, however, so satisfactory that this metal is almost universally employed for such work.

What has already been said regarding the construction of lead-lined tanks is quite applicable to tanks lined with sheet copper or any other thin sheet metal.

Care should be taken to provide a floor, or other supports, beneath a tank of sufficient strength to support it without sagging.

863. Tanks above roofs are usually fitted up a few feet above the roof in order that connections may be conveniently made underneath, and that the tanks may be protected from frost by suitable casings. Tanks in sheltered positions are usually set on flat floors, etc., with the pipe connections leading from their sides.

A tank which is outside, or on top of a building, should be provided with a *wooden housing*, to protect it from frost and from the heat of the sun. Care must be taken, in locating a tank, to avoid the vicinity of soil pipes and vent pipes, and all possible sources of contamination by foul air. All storage tanks, either inside or outside of buildings, should be provided with tight covers to prevent the entrance of dust, etc. The covers should be carefully ventilated, close-meshed brass gauze being used for covering the apertures used for ventilation.

864. The several **pipe connections to a tank** should be carefully located.

The **overflow pipe** should be made with a wide mouth, as shown at *D*, Fig. 222, so as to conduct away a large quantity of water without requiring much head to force it. The supply pipes to the kitchen boiler and to the cold-water system are attached to the bottom at *F* and *G*. The end of the cold-water supply pipe *G* should be extended at least three inches higher than the end of the pipe to the boiler. This ensures that the cold water will fail at the faucets before it fails at the boiler, and that the boiler shall be supplied as long as the tank contains any water.

If the tank is supplied from the street mains, the supply should be controlled by means of a ball-cock and float *I*; if supplied by a pump, the water should be delivered over the side of the tank by the pipe *H*, the mouth of which is turned downwards to prevent spouting or splashing over the sides.

If the supply pipe enters through the bottom of the tank, it should extend above the desired level of the water, and the mouth turned downwards.

To give notice when to stop pumping, a small overflow pipe *E* is connected at high-water level, and its outlet is placed at some visible point near the pump. When the tank is properly filled, water will flow from the **telltale**, and thus indicate the fact to the operator at the pump.

Tanks receiving their water supply intermittently, as from pumps, which have to supply a residence with water, and also supply water to a barn and for sprinkling lawns, etc., are usually provided with two outlet pipes, one of which is connected at a higher level than the other. The object of this arrangement is to cause the supply to the barn, etc., to fail first, as the tank becomes exhausted, and to hold a definite quantity of water in reserve for the use of the dwelling. The stoppage of the water supply to the barn serves as a notice to the attendant to start the pump.

If rain-water be led directly from the roof gutters into a tank, the conducting pipes should not only have strainers in

the gutters, but should also have a movable basket strainer of fine mesh hung on the mouth of the pipe, where it can easily be taken off and cleaned. The coarse strainer in the gutter will keep back leaves and twigs from trees, birds, etc., while the small mesh strainer hung on the tank end will catch all the smaller matter which would otherwise accumulate in the bottom of the tank, decompose, and contaminate the water.

All tanks should have a *washout cock* of large caliber attached to the lowest part of the bottom, so that mud and sediment can be scrubbed and conveyed through it to some convenient point of discharge; or, the overflow pipe may be taken through the bottom of the tank and continued up to two or three inches below the top, with a hollow *brass waste plug and socket connection* at the bottom, so that the *standing overflow* within the tank can be lifted out of the ground socket, and the tank thus emptied. The upper end of the standing overflow should have a funnel mouth.

Large tanks are usually provided with a device to show the level of the water in them. A *float* commonly made of wood rests on the water, and is connected by a wire or cord, and guide pulleys to a small weight or pointer which slides over a graduated scale which is located at some convenient point for observation.

PLUMBING FIXTURES.

SINKS.

865. Sinks are of several varieties; viz., kitchen sinks, butlers' pantry sinks, and slop sinks.

They are made of wood, cast iron, steel, enameled iron, brown glazed earthenware, porcelain, soapstone, slate, etc.

All sinks should be provided with a strainer and waste pipe. The waste pipe should be trapped if it extends to a drain pipe or cesspool; or, even if it is open to the air at the end, it should be trapped to prevent the wind from blowing foul odors back into the house.

Kitchen sinks should be placed where there is plenty of

light, and as near to the pantry as possible, so as to save steps for the persons using them. They should be removed to such a distance from the range that the persons using them will not be subjected to the heat of the fire, and should be set near a window, if possible, to secure plenty of light and ventilation. Sinks should not be encased in woodwork, but left exposed all around, so that no damp places can be maintained. Care should be taken to avoid leaving any crevice or cranny where dirt can lodge or where vermin may breed. If the sink is furnished with a back of any material, the space behind it should be thoroughly filled with cement or plaster of Paris, or it may be left open for access to and ventilation of the parts.

Kitchen sinks should be supported by legs, or placed upon substantial brackets, at a height of about $30\frac{1}{2}$ inches above the floor; i. e., from the floor level to the top or rim of the sink.

866. Wooden sinks are usually fitted with a waste pipe *A* and strainer *B*, as shown in Fig. 258. The waste

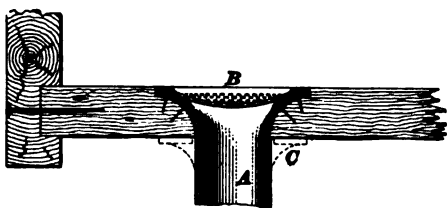


FIG. 258.

pipe is of lead, and is flanged over and secured with copper tacks. The strainer is made of sheet copper, and is sunk flush with the bottom of the sink.

The connection is made water-tight by setting the flanged end of the pipe in red or white lead. This connection can be strengthened by wiping a flange around the pipe at *C*, and fastening it to the woodwork.

Although we describe wooden sinks, and illustrate the waste-pipe connection to same, still we do not recommend their use, because the wood absorbs foul matter which soon decomposes and evolves disagreeable odors. They also tend to propagate vermin.

Wooden sinks may be lined with sheet metal, preferably

copper, weighing 16 to 20 ounces per square foot. The bottom must be secured at several points by solder dots, to prevent bulging when heated.

867. Cast-iron sinks are provided with strainers, and the waste pipe is attached as shown in Fig. 259. The lead

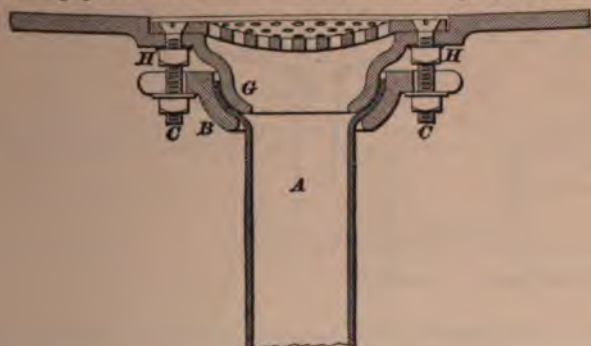


FIG. 259.

waste pipe *A* is flanged over the conical nozzle *G* of the sink, and is held in place by the clamp ring *B* and the bolts *C*. To prevent water from leaking past the heads of the bolts and trickling down upon the outside of the pipe, washers of rubber or leather are set up tight by the nuts *H*.

The several styles and kinds of kitchen sinks can best be studied by the student procuring catalogues from reputable manufacturers; consequently, we consider it unnecessary to treat upon that subject here. Other plumbing fixtures, such as baths, basins, etc., can also be studied from the same catalogues.

868. Butlers' pantry sinks are made of various shapes and materials. The most common are made of sheet copper tinned on the inside. They are either struck up from one piece of sheet copper or are built of two or more pieces.

A copper pantry sink composed of one piece of sheet copper is shown at *a* in Fig. 260. It is oval in plan and semi-oval in section. It is supported by a flange *b*, which is nailed down to the board *c* before the hardwood top *d* is bedded down and secured in position.

This form of pantry sink is always provided with an overflow horn, as shown at *e*, and a plug and socket waste con-

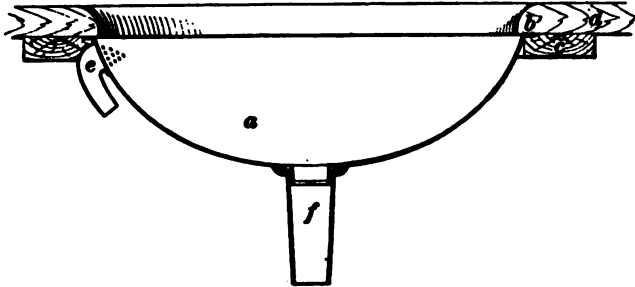


FIG. 260.

nection in the center of the bottom, as at *f*. This is known as an **oval pantry sink**.

869. Flat-bottomed copper pantry sinks are built from flat pieces of tinned sheet copper. Their seams are locked and sweated with soft solder. Their bottoms are flat and the sides are usually slightly rounded at the corners. They are also furnished with a flange *a* around the top, as in Fig. 261, nailed to a wooden frame *b*, which prevents the

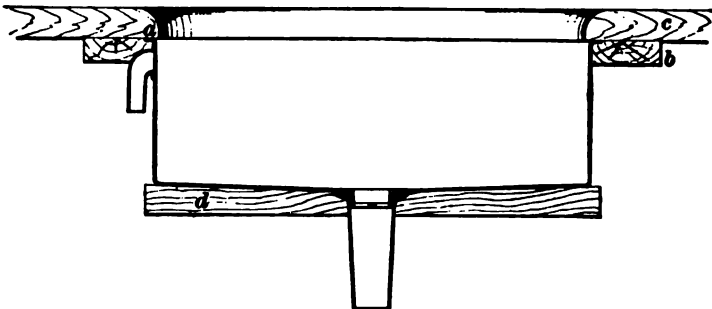


FIG. 261.

flat sides from bulging. The hardwood top *c* is bedded on the frame *b* with red or white lead putty and secured with brass screws. The bottom of this sink should be supported by a shelf *d*, which is "scooped out" in the center, as shown, so that the bottom may be perfectly drained.

870. Porcelain pantry sinks are commonly made with a recess *A* in the back, which affords room for a standing overflow *B*, Fig. 262. This overflow tube is removable

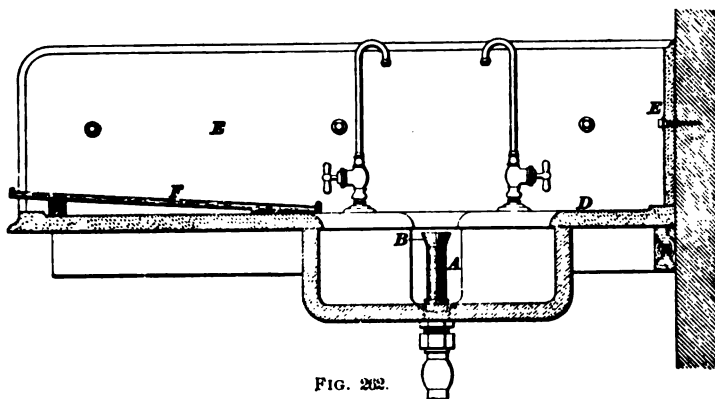


FIG. 262.

from the socket, and serves as a plug which can be pulled up to let the water out.

These sinks are usually fitted with a marble slab *D* and marble splash or wall plates *E*. A *dish drainer F*, made of wooden slats or of rubber, is used to protect crystal or china dishes from contact with the slab, and thus prevent their being broken. The waste connection is similar to that of a wash-basin.

871. Slop sinks differ from kitchen sinks chiefly in dimensions; being smaller in length and width, but of greater depth. They are usually set so that their rims are about 20 inches above the floor.

Slop sinks which receive chamber slops and sewage matter are provided with flushing rims and flush tanks, and are cleansed in a manner similar to washout closets. They are constructed with large traps, and are connected to the drain pipes in a manner similar to the connections of water-closets. They are often supplied with hot and cold water faucets, similar to those used for sinks, and thus do service as "housemaids'" or "chambermaids' sinks." They are usually set in a well-lighted and well-ventilated closet, or other small apartment, convenient to the bedrooms.

872. A **slop hopper sink** is shown at *A* in Fig. 263. It is provided with a strainer *B*, which can be removed to

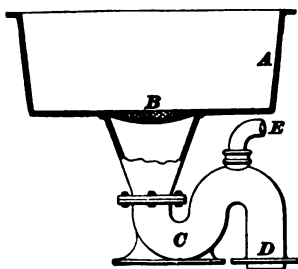


FIG. 263.

clean the trap *C* below. It is supported directly upon *C*, which is a 4-inch trap. The outlet end *D* of the trap is flanged so that it may be attached to a lead waste pipe. The trap may be had without the flange, when it is to be calked into the socket of an iron pipe.

A 2-inch back-vent connection is made to the trap at *E*.

873. *Wood* as a **material for sinks** has some advantages and many disadvantages. Dishes are less liable to break or chip by coming in contact with it than with a metal or porcelain sink. But it absorbs greasy liquids and becomes foul, emitting unhealthy odors. It fosters vermin, and becomes leaky from unequal shrinkage. If it is lined with sheet metal, the inner side of the woodwork has no chance to dry out, and it soon rots. If ventilating holes be made in the wooden bottom, they soon become infested with vermin.

874. The *cast-iron sinks*, plain or galvanized, seem to answer all requirements. To save the dishes from damage, the bottom of the sink may be covered by a grating of wood or rubber, which can be readily removed and cleaned. Other sinks may also be fitted with the same device.

875. *Enameled iron* is a very clean and desirable material for sinks while it is in perfect condition. But the enamel will crack under the action of hot water or heavy blows, and thus admit moisture to the iron beneath, which will oxidize and detach the enamel, causing it to come off in flakes.

876. *Steel sinks* are light and cheap, but are not durable. They rust very rapidly. If they are enameled, the enamel

on the bottom is soon cracked by the bending of the metal, caused by the weight of dishes, etc., in it, and it is soon spoiled, as before explained.

877. *Earthenware or brown glazed sinks* are about 1½ inches thick, and are usually glazed both outside and in. They are quite heavy, and require an iron or other strong frame with legs to properly support them.

The chief merits of glazed earthenware or porcelain sinks are: (1) they are easily kept clean and free from smell; (2) they are practically imperishable.

WASH-BASINS.

878. Wash-basins are in shape either round or oval. The **oval basin** affords more space for the free use of the arms than a round one of the same capacity, and is, therefore, preferred.

Basins are measured over the outside of the top flange. **Round basins** vary in diameter from 12 to 16 inches. Oval basins are usually made in three sizes, 17 × 14, 19 × 15, and 21 × 16. The word "bowl" is now often used instead of basin. It refers only to that part of the fixture which holds the water.

Basins are made of iron, galvanized or enameled, and also of porcelain. The porcelain basins are made in plain white color, or they are decorated to any degree of elegance that may be desired. Wash-basins are constructed in many ways. In the most common variety, the bowl is separate from the **slab**, or top, and the splash plate, or **back**, is also separate from the slab.

In other varieties, the bowl, top, and back are made in one piece of metal or porcelain.

Bowls are made with and without overflows, and the overflows are of several varieties. In Fig. 264 is shown a



FIG. 264.

common round bowl with overflow horn attached. The overflow consists of a strainer *A* and a nozzle, or horn, *B*, to which a waste pipe is attached by a cemented slip joint, or by a rubber cone connection. The latter is preferable.

This form of a bowl necessitates the use of a separate overflow pipe to connect the horn to the waste pipe. In all such connections the overflow connection must be made to the waste pipe on the house side of the basin trap, or to the trap itself and under the water.

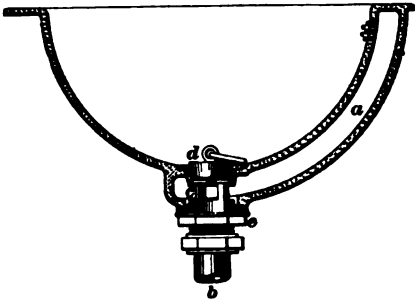


FIG. 265.

879. In Fig. 265 is shown a **bowl and overflow combined**.

The overflow duct *a*, which is molded on the basin, leads into the waste outlet *b* through holes *c* in the connection under the rubber plug *d*.

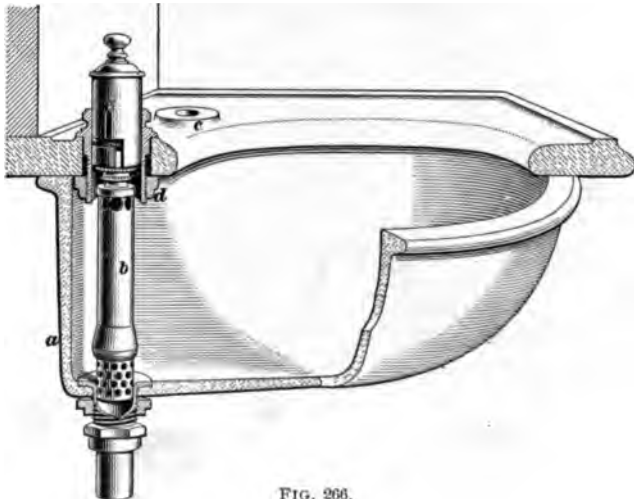


FIG. 266.

880. In Fig. 266 is shown a basin with a **standing overflow** inside a recess *a* constructed in the porcelain

bowl. The standing overflow *b* also forms a waste plug, and is perforated at its base, as shown, to form a strainer, which can be easily cleaned by lifting out the entire waste plug and overflow arrangement. The top of *b* slides in a guide which is secured to the marble top *c* by a lockout *d*. The standing waste is suspended by a bayonet catch, as shown at *e*.

881. A stand-pipe waste and overflow combined is shown in Fig. 267. The bowl *c* is made plain without even

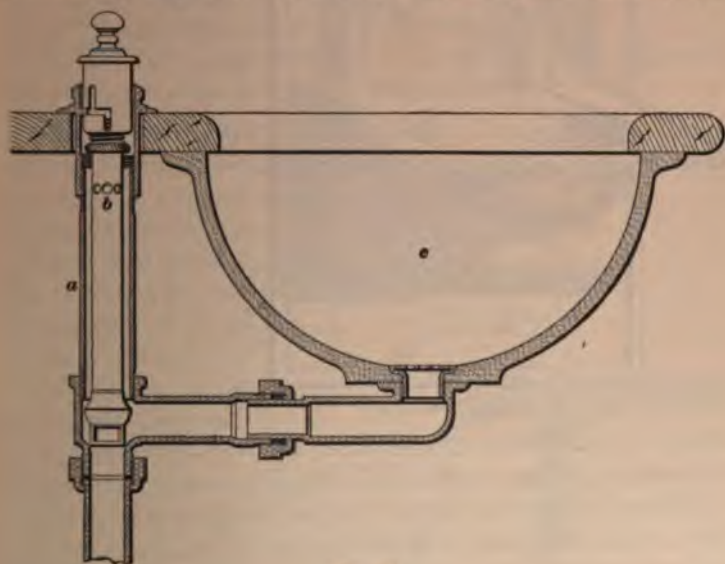


FIG. 267.

a stopper, and has a strainer only. The stopper and standing overflow are contained in the *stand-pipe a*. The surplus water escapes through the holes *b*. This construction is explained in Art. 888.

Bowls are also made with *flushing rims*, and the faucets are placed below the top, having only the handles in sight. The rim of the bowl is thus freed from all obstructions, and the hands of the bather can not be injured by the nozzles of the faucets.

Wash-basins are supported upon substantial wall brackets, or upon metal frames or pedestals. They should never be

cased in with cabinet work, because such enclosures can not be kept clean, and vermin will find lodgment in the crevices of the woodwork.



FIG. 268.

Two swing cocks *a* supply hot and cold water to the basin when their nozzles are swung around until they are over it. The water in the wash-bowl *b* is emptied into a receiving tank or chamber *c*, when the bowl is raised and the apparatus closed, and is carried away by a waste pipe whose trap is immediately under the tank.

883. Bowls are attached to marble or slate top slabs by means of **basin clamps** *E*, as shown in Fig. 269, three clamps being used for a round bowl and four for an oval bowl. The bolts are attached to the

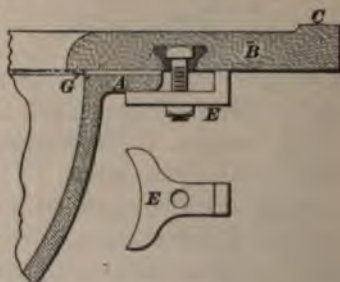


FIG. 269.

slab by means of lead calking. The rim of the bowl is bedded against the slab with plaster of Paris, as at *G*, to make a water-tight joint.

The proper height of top of slab *B* from the floor varies from 30 to 31½ inches, the former being generally satisfactory.

The **slab**, or top, should have a raised rim around its entire perimeter, as at *C*, so that splashes of water will drain back into the bowl. The holes for basin cocks and other attachments should also be surrounded by raised rims, for the same purpose. The holes for ordinary basin cocks should be made square to receive the square shank of the cock, and thus prevent it from turning.

884. The **basin cocks** should be attached as shown in Fig. 270, a lead washer *a* being used between the marble slab and the nut *b*. The **chain stay** should be fastened in the same manner. The cocks and chain stay should be set in plaster of Paris.

The connection between the waste pipe and the discharge outlet of the basin is commonly made by means of a plug and socket having a screw coupling, as shown in Fig. 265. Great care must be exercised in screwing up this joint because the bowl is very liable to crack or break at this point. A thick gasket of soft rubber should be used between the locknut *c* and the porcelain.



FIG. 270.

885. A cheap connection can be made by means of a short **rubber sleeve** *R*, Fig. 271, which is tied or wired to both basin and pipe. This allows the fixtures to settle and shift without danger of rupture.

This method of making basin connections is not to be

recommended for good work, because the rubber soon decays, becomes brittle, and breaks away.

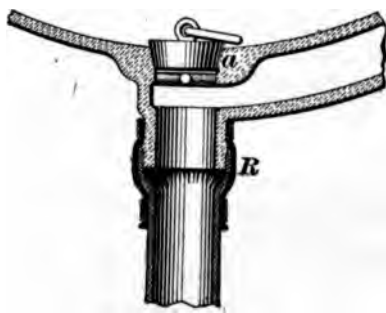


FIG. 271.

The seat, or socket, *a* to receive the plug, when molded in the porcelain, is always more or less imperfect; consequently, a *soft rubber plug* is used.

The space between the splash plates and the wall should be completely filled with plaster of Paris, so that no crevice or hole is left for vermin.

BATH-TUBS.

886. The sloping end of a bath-tub is called the **head**, and the vertical end is the **foot**. They are made in three general styles, the *ordinary*, *French*, and *Roman*, the difference being in the shape.

The **ordinary** style has a round bottom, with sloping head and vertical foot.

The **French** style has a flat bottom and flat parallel sides, with rounded corners. The head slopes and the foot is vertical.

The **Roman** style is rectangular, the sides, bottom, and ends being flat, with round corners. Both ends and sides are nearly vertical.

The ordinary style requires the least water, but the bottom being semicircular in form, is of inconvenient shape to stand upon.

The French tub affords more room for the bather, but requires more water. If they are lined with sheet metal, the linings must be well secured to the sides and bottom to prevent them from bulging when heated by the warm water.

The Roman bath gives most room for the bather. It is designed chiefly to overcome the unbalanced appear-

ance which the other forms present when fitted up elsewhere than in a corner. In this style the faucets are nearly always located outside the tub, and the hot and cold water enters through a single opening. The interior space is thus clear from all obstructions or projections upon which the bather might be injured.

The cheapest grade of baths are those made of wood and lined with zinc or tinned copper. Such baths are encased with wood finishings and have a special top made to fit the bath and the position in which it is placed.

Open copper-lined and aluminum-lined baths are clad by a steel or indurated fiber casing, supported on four cast-iron feet, and have the top rim 3 or 4 inches wide all around, attached to the bath.

A sheet of non-conducting material, such as asbestos, is placed between the lining and metallic casing. The tin coating soon wears off, and exposes the copper. A harder and more durable coating is secured by nickel-plating.

Bath-tubs are also made of cast iron, and are used with or without protective coatings. The best grade of iron tubs are coated with porcelain enamel.

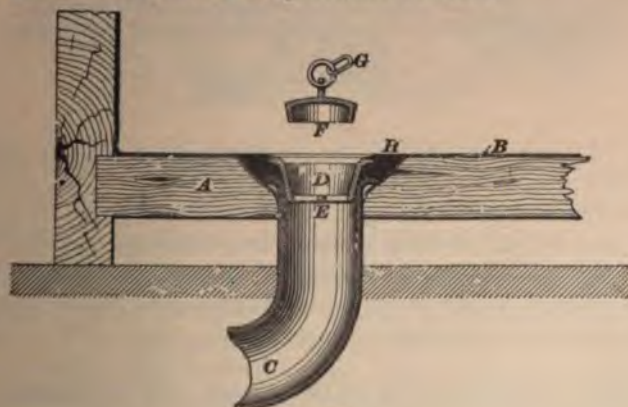


FIG. 272.

The finest grade of bath-tubs are made of porcelain, or of a fine fireclay body with a heavy porcelain enamel. They are finished white, or are decorated to any degree

desired. Iron and porcelain tubs are usually supported by detachable feet, and are usually set upon marble safes.

The waste pipe is always connected to the bottom of the tub, and should be provided with a strainer to prevent the passage of soap, rags, etc., into the trap. The mode of connecting the waste pipe to a common copper-lined bath is shown in Fig. 272. The wooden bottom *A* is *countersunk*, and the copper lining *B* is also countersunk to suit. The waste pipe *C*, which should be not less than $1\frac{1}{2}$ inches, inside diameter, is flanged over, as shown. The brass socket *D* is provided with cross-bars *E* which serve as a strainer, and is ground to a water-tight fit with the plug *F*. The space *H* is filled with solder, flush with the lining.

All tubs should be provided with an overflow pipe, having a perforated plate or strainer over its mouth to keep out

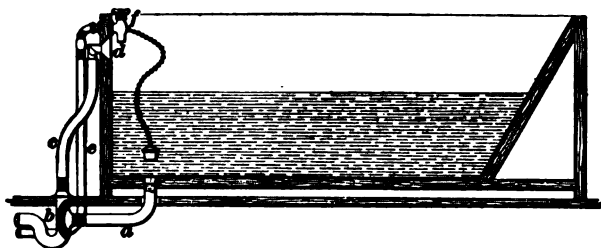


FIG. 273.

soap, etc. A common form of copper-lined wooden tub is shown in Fig. 273.

The bath empties through the $1\frac{1}{2}$ -inch waste pipe *a*, through the $1\frac{1}{2}$ -inch half S trap *b*, into the drainage system. A $1\frac{1}{2}$ -inch lead overflow pipe *c* connects the copper overflow pipe horn *d* to the trap. A $\frac{5}{8}$ -inch or $\frac{3}{4}$ -inch lead pipe *e* supplies the bath with water through the bath cock *f*.

887. Standing overflow and waste pipes are frequently used, as shown in Fig. 274. The overflowing water passes over the top of the standing tube *a*, and when the tub is to be emptied, the tube is pulled upwards, thus uncovering the perforations at the bottom of the inner tube *c*.

as shown. The outer tube is provided with a rubber ring *d*, which makes a water-tight joint with the seat when it is dropped down upon the bottom. A bent coupling *e* is shown attached to the waste outlet. If desired, a straight coupling

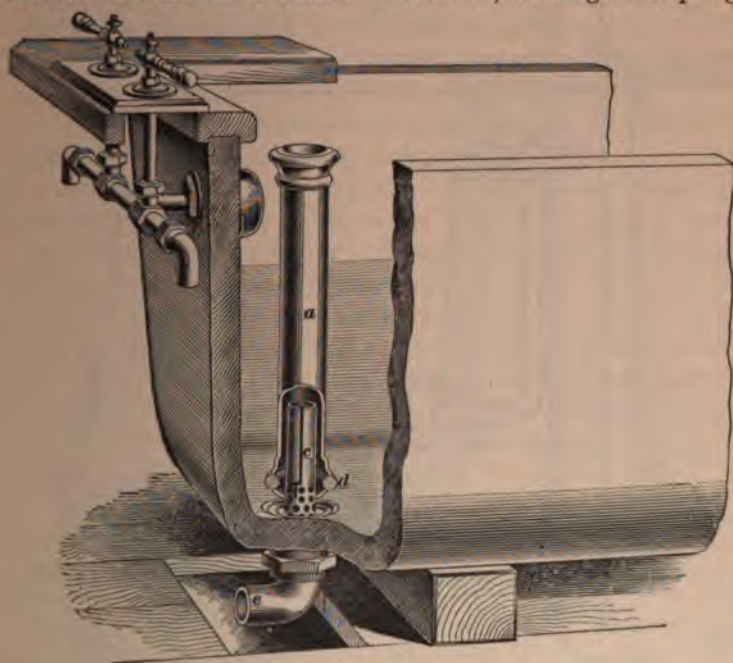


FIG. 274.

shown by dotted lines may be used. This coupling connects with the bath trap, which is not shown here.

888. A stand-pipe combination of waste and overflow is shown in Fig. 275. The tube *a* is provided with a rubber ring *b* which shuts down water-tight upon the seat *c*. The water rises between the tubes *a* and *d* to the same height that it does in the bath, until it reaches the perforations *e*; it overflows through these and passes down the interior of *a* to the waste pipe. The inner tube is provided with a handle *F* having a suitable slot and catch, commonly known as a **bayonet catch**, by which it can be lifted and suspended, as shown.

These combined waste and overflow devices are adapted to all kinds of bath-tubs, whether of wood, metal, or porcelain.

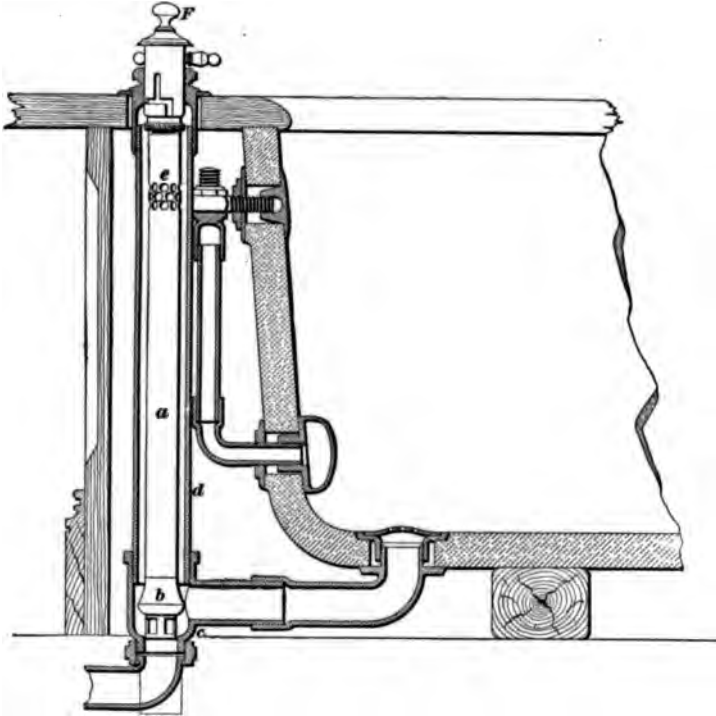


FIG. 275.

889. The hot and cold water may enter the bath through separate faucets. They are, however, generally delivered to the bath through a single **bath cock** composed of the hot and the cold shut-off valves joined together into one discharge nozzle. Such a fixture is usually nickel-plated. It is known as a *combination bath cock*. The valves of the cock may be inside or outside the bath. Ground key cocks are seldom used as bath cocks. "Fuller" and compression valves are mostly used.

The faucets which are used to control the water supply are of both kinds; plug cocks are used only on very low-pressure work. Compression cocks are mostly used. The

hot and cold water faucets are commonly made in one piece, with a single discharge nozzle.

In the best grade of fittings, angle valves with brass screw-joint connections are employed, and they are arranged to deliver water into the tub through the same nozzle. All the valves and pipes are thus located outside of the tub, and the whole interior space is free of obstructions.

It is quite common practice to arrange the bath cocks so that they will supply the bath from points near the bottom, as shown in Figs. 275 and 276. This method certainly is less noisy than that in which the nozzles are always above the water in the bath, but it nevertheless has a disadvantage which should prohibit its general use. For instance, suppose the bath to be full of foul water and soap, etc.; a heavy draft is then made on the main by somebody opening faucets at lower levels. The bath water will immediately be "sucked," as it were, up through the combination cock (if it is open) and then be siphoned down through the supply pipes, thus contaminating them.

Sometimes the hot and cold water faucets are connected to deliver into the outer shell of the standing waste, so as to supply the tub through the waste-pipe strainer. This is a

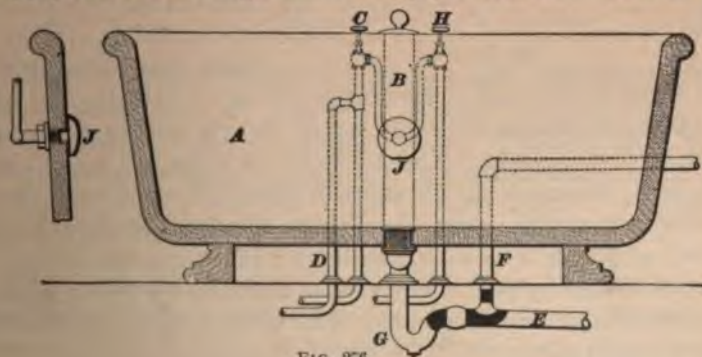


FIG. 276.

bad plan, because when the tub is emptied the water passes out first and all soap or refuse goes last. This tends to lodge in the waste pipe, and it will be washed back into the tub if the fresh water is introduced in that way.

890. Fig. 276 shows the arrangement of the **connections to a porcelain Roman bath A**. The standing waste *B* and the supply faucets *C* and *H* are placed at the side of the tub, between it and the wall. The mingled hot and cold water enters through the single nozzle *J* which is usually made in the form of a "shell," as shown at *J* in the section to the left of the figure. *C* is the hot-water faucet, *D* is the hot-water circulation pipe, *E* the waste pipe, *G* the trap, *F* the trap vent, and *H* the cold-water faucet. The standing waste *B* is shown in section at *d* in Fig. 275.

891. Metal and porcelain tubs are made with two styles of rim, called plain or roll, as in Fig. 277. The **plain rim**

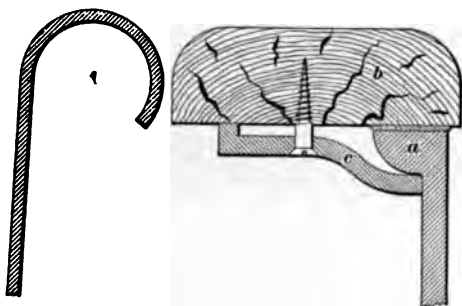


FIG. 277.

a needs a wooden top or rail *b* to cover the square edges and protect the bather, and to improve the appearance. The wooden top may be secured to the rim of an iron tub by clamps *c*, as shown. The **roll rim A** requires

no other finish, and is free from decay or vermin.

Bath-tubs which are to be cased in are usually set on a copper or lead safe. Those which are to be left open are generally set upon marble safes or upon a floor of some impervious material. Marble safes are usually dished out to a depth of $\frac{1}{4}$ or $\frac{3}{8}$ of an inch, and have a brass strainer connection to a waste pipe. They should always be set on a small inclination, so that the water will drain properly towards the waste strainer.

The sizes of copper bath-tubs range from $4\frac{1}{2}$ to 6 feet long, 24 to 26 inches wide, and 20 to 22 inches deep. Iron bath-tubs are usually about 19 inches deep. Porcelain baths are wider, being usually 30 inches at the head and 24 inches at

the foot, and are about 22 inches deep. They are quite heavy, a tub $5\frac{1}{2}$ feet long weighing about 600 pounds.

892. Sitz, or seat baths (see Fig. 278) are of smaller dimensions than the plunge baths previously described, being from 24 inches to 27 inches long, 22 inches wide, and 12 inches to 17 inches high at the front edge, when set up. The back is usually 6 inches, or more, higher than the front.

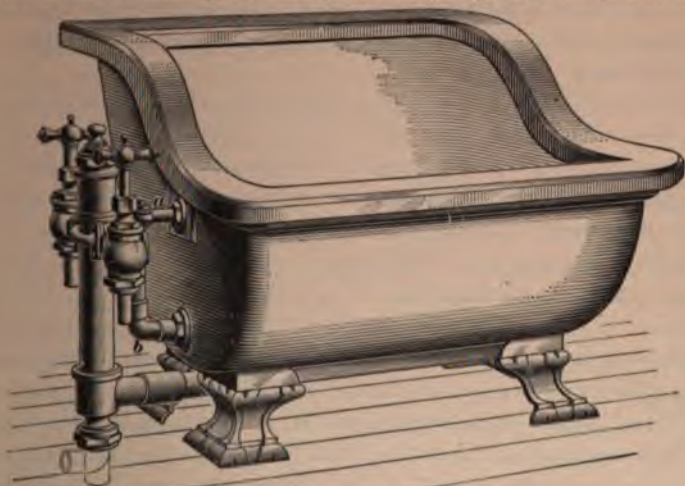


FIG. 278.

The sitz bath is fitted up with hot and cold water and waste connections in a manner similar to those already shown and described for plunge baths. The hot and cold water valves and the stand-pipe are rigidly secured to the side of the bath by a brace *a*. The hot and cold water mixes and enters near the bottom by the tube *b*.

893. Foot baths are of about the same dimensions as seat baths; some, however, are only $17'' \times 19''$ and $10''$ deep. Seat and foot baths are constructed of the same materials, and are connected to the waste pipes in the same way, and are provided with the same fittings as the full size baths.

894. Shower Bath.—The apparatus for a **shower bath** consists mainly of a large sprinkler, which delivers

the water downwards in fine streams like a shower of rain. The sprinkler, which forms an attachment to the bath, should be set at a height of $6\frac{1}{2}$ to 7 feet above the bottom.

The chief objection to plunge baths is that skin diseases are liable to be transmitted from one bather to another, unless the bath is thoroughly scrubbed after each bather has used it. For this reason plunge baths are objectionable for public use; they are, however, considered quite safe for family use.

Hospitals, asylums, etc., must be provided with a large number of baths to accommodate the patients, and as each plunge bath occupies a large area (about 12 square feet) it is often found that sufficient space can not well be obtained for the desired number of baths. In such cases, spray, or shower baths, or a combination of both, are often used. Such baths are composed of a sprinkler or shower nozzle attached to the end of the water-supply pipe, at a point about 7 or 8 feet above the floor, which is made water-proof and furnished with safe strainers at suitable points. The chief merit of the shower, or **rain bath**, as it is sometimes called, is that excretions or scales from one bather's skin can not possibly come in contact with another bather. The shower bath apparatus is so arranged that hot or cold water can be obtained as desired by regulating the discharge of hot and cold water cocks, or if steam is the heating agent, by regulating the volume of steam discharged into the cold water as it flows through the feed tube to the nozzle.

The best method of heating the water by steam is to place a copper or brass tube inside the cold-water feed-pipe, admit steam into the top, and have a drip-pipe from its base to carry off the water of condensation. The cold water becomes heated as it flows around the steam tube towards the nozzle. A graduated disk, representing the resulting temperatures when the valves are opened, should be attached to the steam valve so that the handle can be turned just enough to admit sufficient steam to give the desired temperature to the water. As a safeguard, how-

ever, a thermometer should be attached to the water pipe before it reaches the nozzle.

In a tub or plunge bath the water is cleanest when bathing is commenced, and at the period when clean water is most required, that is, at the finish of the bath, the water is most foul. In a rain bath, however, the water is clean at all times, because it is continually changing and none of the water comes in contact with the person more than once.

Needle and spray baths consist of a frame of perforated pipes, which partially surrounds the bather. The water is projected horizontally in fine streams or spray upon all parts of the body above the knees.

895. The **douche** is designed to project a stream of water upwards from the floor, either in a solid jet or in a spray. The jet is often attached to the strainer, which is set in the middle of the safe. All three varieties are often combined with the shower baths.

All jet or spray baths are provided with suitable hot and cold water pipes, which deliver the water into a mixing pipe before it leaves the jet. The mixing pipe should be provided with a thermometer, so that the temperature may be regulated before the bather exposes himself to the water. The thermometer must be so enclosed that its bulb or mercury chamber is in actual contact with the water, otherwise the indications will be very unreliable.

If the entire bath-room floor is not water-tight, a *rubber-cloth curtain* should be hung by rings from a suitable rod overhead, so that it can be drawn together and be made to enclose the whole apparatus. This will prevent the water from falling outside of the safe in which the apparatus is located. The curtain should be open at the top.

Jet and spray baths are frequently set up within a stall or alcove, which is lined with marble slabs, or other impervious sheathing. They are also combined with bath-tubs usually of the Roman or French style.

The floor room required for a shower or spray bath is usually from $3\frac{1}{2}$ to 4 feet square.

Many good spray, shower, and douche combinations can be seen illustrated in the catalogues of any reputable manufacturer or plumbers' supply house.

896. Bidets consist of a pan having a seat like a water-closet and a jet of water which is projected upwards, as

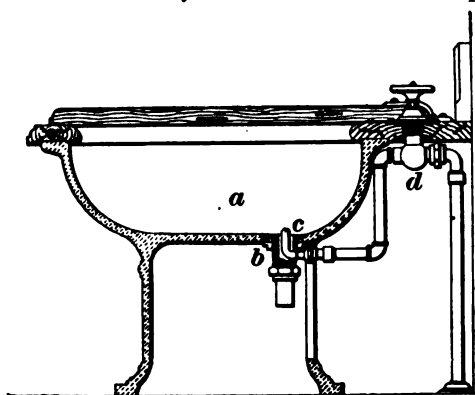


FIG. 279.

shown in Fig. 279. The pans are made of porcelain or of copper, and are also made in one piece with the support, as shown in the cut. They are usually fitted with hot and cold water connections and with a mixing pipe which should have a thermometer attached, to indicate the temperature of the water. Sometimes the pans are fitted with a standing overflow and waste plug, by which water may be retained in the pan.

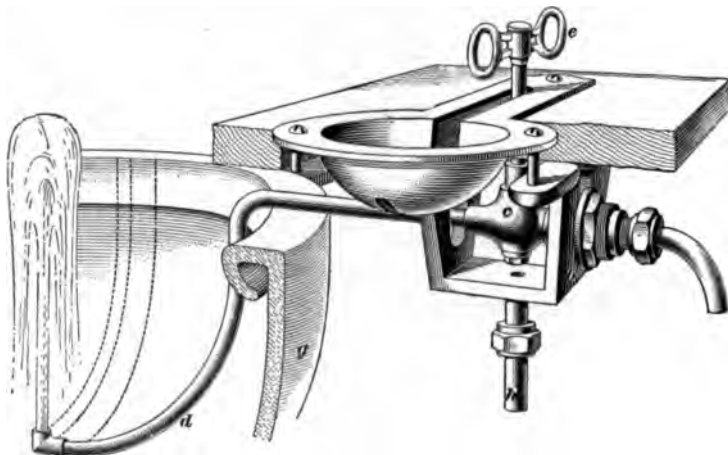


FIG. 280.

In Fig. 279 the bowl or pan *a* is fitted with an open

waste connection *b*, through which projects a small jet nozzle *c*. The force of the jet of water ejected from *c* is governed by the valve *d*.

To have the use of a bidet jet without a special bidet bowl, as in Fig. 279, a **bidet cock** can be attached to an ordinary water-closet seat, Fig. 280, by means of a clamp *b*, secured to its under side. The ground cock *c* to which the jet arm *d* is attached works on a swivel in such a manner that when the handle *e* lies in the cup, and the jet arm *d* consequently raised to a horizontal position at the back of the closet bowl *g*, as shown by dotted lines, the water will be shut off and *d* will be concealed under the seat. These attachments are usually supplied with cold water only. A small drip-pipe coupling *h* is usually connected to a $\frac{1}{2}$ -inch waste tube to carry off any drippings from *c*.

LAUNDRY TUBS.

897. Wash-tubs are made of many materials. The cheapest varieties are made of wood, the ends and partitions being rabbeted into the sides and bottom. The joints should be well painted with white lead, and should be drawn tight by means of iron bolts. Repeated drying and wetting soon spoils the joints and rots the wood. When they become leaky past repairing, they may be lined with tinned copper, galvanized iron, or zinc.

Iron tubs, either galvanized or porcelain enameled, are cleanly, durable, and generally satisfactory.

The only drawback to enameled tubs is that the enamel will eventually crack and peel off. The corners are all rounded, and no crevices exist in which dirt may accumulate or which will harbor vermin.

When the enamel is peeled off and the iron body is consequently exposed, the rust formed by the iron discolors the water and spoils it for washing purposes.

Porcelain tubs, or the **brown glazed earthenware tubs**, are very heavy, and require a substantial iron frame to support them. They are very durable and are easily

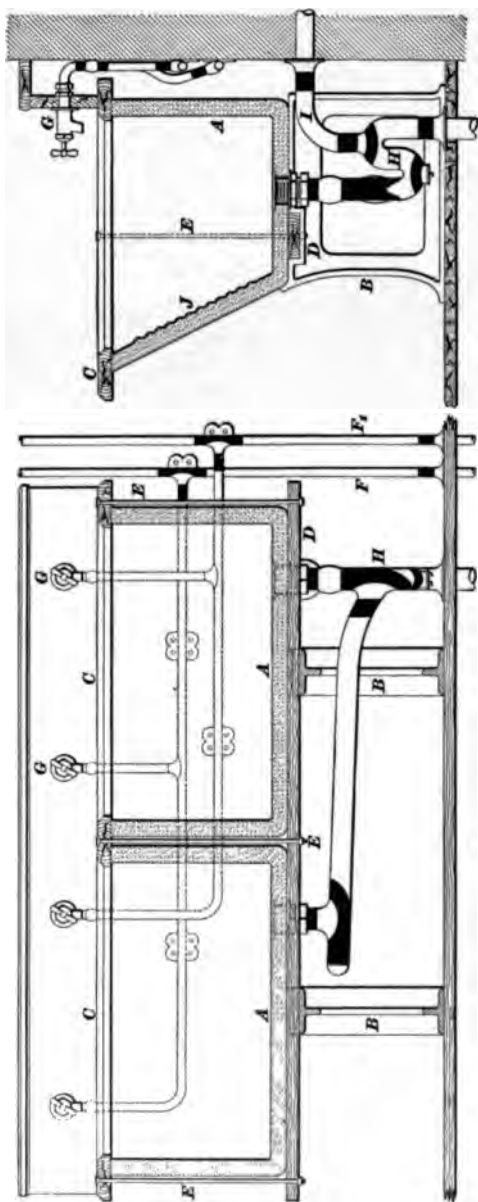


FIG. 281.

kept clean. The corners are all rounded off to prevent accumulations of dirt. If finished flat on top they are usually supplied with wood rims of ash to protect their edges. The rims should be set in red lead putty before being bolted down tight.

Porcelain tubs of the finest grades are usually finished on top with a *roll rim*, which requires no wood rims.

Tubs are also made of **soap-stone** or **slate slabs**, which are joined by red lead cement and are held together by rods and iron frames. Inferior soapstone will crack if subjected to hot water. They are liable to accumulate grease and dirt in the sharp corners unless carefully cleaned.

Cement tubs are often used on the cheapest work, and have been found to serve the purpose well when made from the best Portland cement.

898. In Fig. 281 is shown a set of two porcelain, or glazed earthenware, wash-tubs *A*. They are set upon two cast-iron stands *B*. An ash frame *C* is bolted to a hard wood strip *D* by long bolts *E*. Branches are taken from the hot and cold lead water pipes *F*, *F*₁ to supply the tub cocks *G*.

The waste water from the tubs passes through a lead **S** trap *H* connected as shown. The trap is protected against siphonage by a 1½-inch lead back-vent pipe *I*. One of the tubs has part of its inner surface corrugated as at *J*. This is often used as a scrub board.

Laundry tubs are sometimes fitted with **wooden covers** which are hinged at the back. When these are used, the faucets must be placed *within the tubs*, the connections being made through holes in the back.

This arrangement is objectionable, because the faucets occupy too much of the interior space of the tubs. The fabrics will catch and tear on the nozzles of the faucets, and the laundress is likely to bruise her hands upon them.

Tubs vary in length from 24 to 30 inches, and in depth from 14 to 16 inches. They are usually 22 to 24 inches wide at the top, and taper upwards on the front side to 15 inches or more at the bottom. They are generally set up in *groups of three*. The rim of the tubs should be set about 32 inches above the floor.

Each tub should be fitted with an outlet plug and strainer, but an overflow connection is not strictly necessary. In fact, the best tubs on the market are not fitted with overflows.

It is necessary only to have overflows on tubs which are set over apartments—such, for example, as on the several floors of apartment houses or flats. These may all be connected to one waste pipe. One 2-inch trap is sufficient for the three tubs. Each tub should have its own hot and cold

water faucets. The faucets should, if practicable, be placed above the tubs, as in Fig. 281.

In fitting up a set of tubs, provision should be made for attaching a clothes-wringer to the right-hand end of the right-hand tub, with a space of at least two feet between this tub and any wall to the right for a clothes-basket.

WATER-CLOSETS.

899. Water-closets are made in many styles, and are constructed to operate in many ways. They are made of porcelain, in one piece; or partly of porcelain and partly of iron; or entirely of iron. The iron is either plain or enameled. The porcelain closets are made either plain white or in colors, and are embossed and decorated to any degree desired.

The duty of water-closets is to thoroughly remove all filth that may be deposited in them. They must be free from odors, and must prevent the escape of drain air from the soil pipe into the dwelling.

To meet these requirements, every closet must fulfil the following conditions:

1. *The water used for cleansing must be applied in such a manner that it thoroughly washes all the interior surface of the bowl;*

2. *The current must have sufficient force to detach all filth from the surface of the bowl;*

3. *The water must be of sufficient quantity to wash out all the filth and carry it beyond the trap and into the soil pipe; and,*

4. *When the flushing operation has ceased, the closet bowl and trap must be properly filled with fresh water, the foul water being entirely removed.*

The thorough washing of the interior surface of the bowl is accomplished by introducing the water through a **flushing rim**, which forms part of the closet bowl, as at *R* in Fig. 282. This, when properly made, will direct the water

in small streams over the whole internal surface. If any part of the surface be left unwashed, it will accumulate filth and emit bad odors.

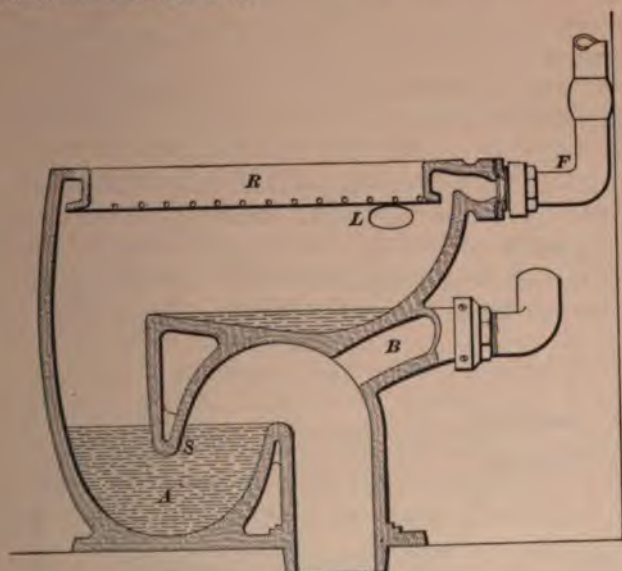


FIG. 282.

The effectiveness of the current of water will depend greatly upon the shape given to the bowl, and upon the rapidity with which the water is projected into the bowl and trap.

900. A superior form of bowl is shown in Fig. 282. The bottom is of large area and is comparatively shallow. This shape is called a **washout closet**. The depth of water remaining in the bowl should be $1\frac{1}{2}$ to $1\frac{3}{4}$ inches at the deepest point.

Water is supplied to the closet bowl through the $1\frac{1}{4}$ -inch flush pipe *F* and the perforated flushing rim *R*, the largest volume entering the bowl at the back. If the basin is deeper, the fresh water may pass under the solid excreta and fail to remove it before the flush is exhausted; and if the basin is shallower, the excreta may adhere so strongly that

it can not all be washed away without using more water than can be allowed.

The soil-pipe branch and trap are ventilated by the *back-vent* connection *B*, which joins a vent stack. The bowl may be ventilated by attaching a pipe to the *local-vent* connection *L*. This, however, is seldom done unless the pipe can be run inside or near a warm chimney, as explained elsewhere.

The lip *S* forming the seal of the trap *A* should dip not less than $1\frac{1}{2}$ inches nor more than $1\frac{3}{4}$ inches below the standing water in the trap. If it is submerged to a greater depth, the excreta, paper, etc., will require a larger and more forcible supply of water than can be allowed to carry

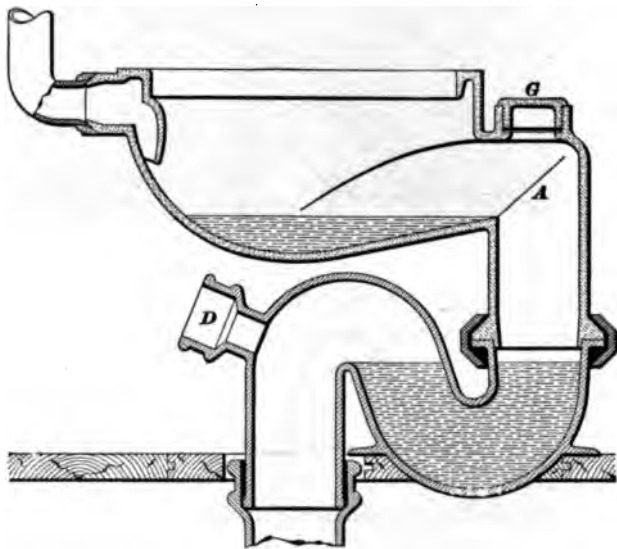


FIG. 282.

them down under the lip and expel them out. If the submergence of the lip be less than $1\frac{1}{2}$ inches, there is danger at times of its failing to properly seal the trap. The variety shown in Fig. 282 is called a **front outlet washout water-closet**; they are also made with the outlet at the side or at the back, as desired.

They are also constructed with the bowl separate from the trap, the bowl being of porcelain and the trap of iron. This permits the trap to be firmly calked into the cast-iron soil pipe, ensuring a strong joint at that point.

901. A side outlet washout closet having an iron trap is shown in Fig. 283. Both the side and back outlet patterns have a slight disadvantage when compared with the front outlet shown in Fig. 282. The top part of the chamber *A* is liable to be imperfectly cleaned, and will become foul and emit bad odors. The front outlet pattern is free from this drawback. The attachment at *D* is to ventilate the soil-pipe branch. The opening at *G* is for a local vent pipe to carry off odors from the basin, and prevent them from escaping into the room either while the closet is in use or when standing idle.

902. The variety shown in Fig. 284 is called a siphon-jet closet. The contents of the bowl are sucked out by the siphon, which is formed by the two tubes *C* and *D*. Some

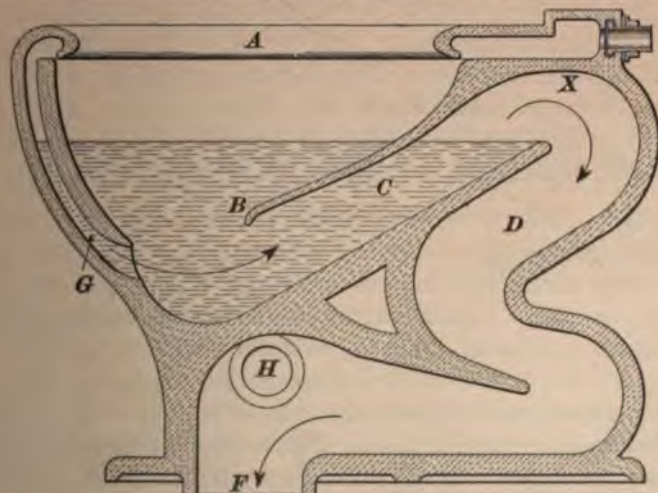


FIG. 284.

of the water which enters the flushing rim *A* rushes down the tube *G*, forming a strong jet, which drives the water in

C up into the space *X* and fills the tube *D*. As *D* is longer than *C*, they act as a siphon until the water in the bowl falls below the lip *B*.

The closet outlet horn *F* is attached to the soil-pipe branch. The back-vent pipe *H* ventilates the closet branch and prevents the bowl from being siphoned by the discharge of other fixtures into the same stack.

Washout closets make some noise while emptying, but the siphon-jet variety are nearly noiseless.

In the latest forms of siphon closets the back-vent horn *H* is dispensed with altogether, and instead of the back-vent connection being made to the porcelain, it really is made to the soil-pipe branch under the floor and as near to the closet as possible.

903. A **pneumatic siphon closet** is a closet in which the siphonage is induced by a partial vacuum being formed in the long leg of the siphon.

Closets of this class are usually provided with a trap under the floor, although some are made with the trap combined in the earthenware or porcelain body of the closet, and directly under the bowl. The bowl, of course, is trapped also by a lip, as shown at *B* in Fig. 284. The space between the two traps contains air, and when this air is extracted, water in the bowl immediately flows into the chamber to replace the air, and in this way the siphon is started.

904. The process of extracting the air is simply that of applying an injector-like connection at the top of the flush pipe and connecting it by a small pipe to the space between the closet traps. As the water falls in the flush pipe and flows into the closet bowl, it draws, as it were, air from the chamber between the closet traps, which otherwise is air-tight.

An objection to this form of closet is the fact that the air between the traps is delivered into the atmosphere of the room as soon as it is liberated from the water in the closet bowl.

The pneumatic siphon closet, however, has several merits which are not possessed by ordinary siphon-jet closets. For

example, if a pail of water is thrown into a siphon-jet closet of the form shown in Fig. 284, the closet bowl is immediately siphoned out and the seal, to a certain extent, is lost if the tank is not flushed at the same time to refill the bowl. This, however, can not occur with a properly designed pneumatic siphon closet, because the bowl will simply fill up to the top before the air lock can be forced.

905. In another variety, called **plunger closets**, shown in Fig. 285, the emptying of the bowl is controlled by a valve or plunger, *P*. This is provided with a rubber

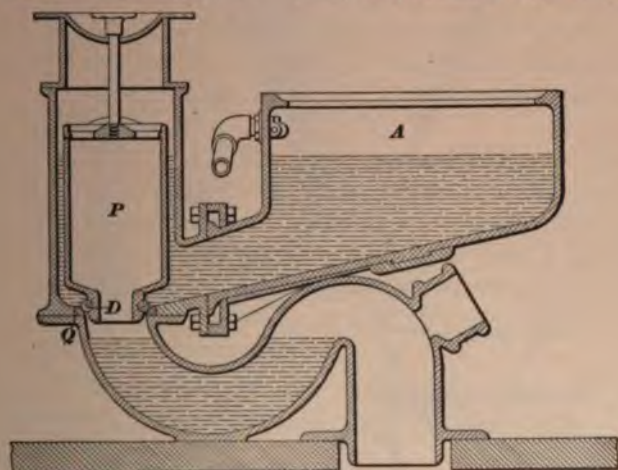


FIG. 285.

ring *D*, which seats upon a brass ring *Q* and makes a water-tight joint with it. The plunger also acts as an overflow, because if the water rises higher in the bowl than the top of the plunger it will flow over and down through the inside, past the valve and into the trap.

The drawback to this style of closet is that the chamber in which the plunger works is imperfectly cleaned and is liable to become foul. Unless the plunger is lifted well up when emptying the bowl, pieces of paper or matches, etc., are likely to stick between the rubber ring and the valve seat, and prevent the closing of the valve. That would

allow the water to leak out of the bowl, leaving it dry if the closet is supplied by a self-closing valve or by a small tank overhead. If the closet be used when the bowl is dry, the excreta will adhere so strongly that the amount of water usually furnished by the flushing apparatus will be insufficient to remove it, and as the water again leaks away, it will remain in the bowl and become a nuisance.

If the closet is supplied by a ball-cock placed in the plunger chamber, a uniform water-line will be maintained in the bowl, and if the plunger valve should leak, a waste of water would be the result, which can not well be detected. This variety of closet is constructed of one piece of porcelain or partly of iron, as shown. Usually all the iron parts, including the plunger, are porcelain-lined.

906. An old variety of closet, called the **pan closet**, has a hopper or conical bowl to receive the excreta, and the lower end is closed by a pan, which is swung on a hinge by means of a lever and pull. This pan catches and retains enough of the flushing water to seal the mouth of the bowl.

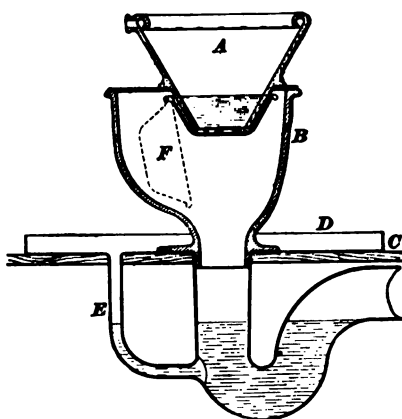


FIG. 286.

It is a very imperfect apparatus. It should always be replaced with a closet of modern construction.

The principle of action of the pan closet is shown in Fig. 286. The porcelain bowl *A* is set upon a cast-iron trunk *B*, which is screwed to the floor *C*. A lead safe *D* is usually set under the closet, and is erroneously connected to the closet trap by a safe pipe *E*. The copper pan *F* seals the basin, and receives the excreta. When the closet handle is raised, the pan drops and takes the position shown by dotted lines at *F* and discharges its contents into the trunk, while at the same moment

a volume of foul air enters the room from the trunk. It has many other serious imperfections, too numerous to mention. Pan closets are universally condemned by all health authorities.

907. The variety called the **hopper closet** is shown in Fig. 287. The bowl is of conical form and is attached to a trap of any desired shape. They should be provided with a



FIG. 287.

flushing rim in all cases, if used inside a building. If they are used without a flushing rim, they become very foul and emit a constant stench.

The **long hopper**, or "Philadelphia hopper," as it is sometimes called, is simply a long closet bowl having the form of a frustum of a cone, and having a 4-inch outlet horn dropping down through the floor, and a floor flange cast on as a base for the closet to rest upon. It is also provided with a flushing rim and inlet horn similar to other water-closet bowls. A long hopper is suitable only for outdoor situations. Hopper closets are seldom supplied with enough water to keep them reasonably clean, and they need to be thoroughly scrubbed every day. A pailful of water should be occasionally thrown down the hopper to forcibly relieve the trap of the accumulation of paper and filth, which would otherwise choke it.

The hoppers and traps are made of solid porcelain or of iron, either plain or enameled. The traps for long hopper closets are placed underground clear of the frost, a straight vertical 4-inch pipe joining the trap to the hopper. (See *n*, Fig. 365).

908. Water-closet seats are of many forms, but very few of them have a proper shape. Several State Boards of Health have settled upon the shape shown in Fig. 288 as the best form, and recommend its general use. They say, "The hole in the seat should be long from front to back, but narrow from side to side. It should never be made circular, as carpenters will do, unless otherwise instructed. The proper dimensions are 11" $\times$ 4". The edges should be moderately beveled. This shape will make the act of relief much easier and tend greatly to prevent that painful disease, hemorrhoids."

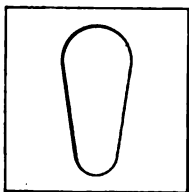


FIG. 288.

Seats for *hopper* and *washout* closets are usually hinged to a back-piece, which may be attached to the wall. The most improved patterns of closets are provided with lugs, to which the seat and cover may be hinged directly. All cabinet work or boxing of any kind should be avoided in setting up water-closets.

No opportunity should be allowed for the lodgment of dirt or vermin. All the surroundings of a water-closet should be kept strictly clean, and all arrangements of covers, pipes, traps, and safes should be made with that end in view.

Seats and covers should be provided with rubber blocks or buffers of sufficient size and elasticity to prevent any damage by their falling down upon the porcelain bowl.

909. The soil-pipe connection, that is, the joint between the outlet of the water-closet or trap and the soil pipe where it passes through the floor, is a matter of great importance. The common joint which is made with putty, the flange being screwed to the floor, is rarely air or gas-tight, although it may not leak water.

Porcelain closets are commonly attached by means of a **brass floor plate joint**, as shown in Fig. 289. The soil-pipe branch *C*, if of lead, is soldered to a brass flange *D* which is screwed to the floor. A rubber gasket *A* is put between the flanges, and the porcelain closet flange *B* is screwed down

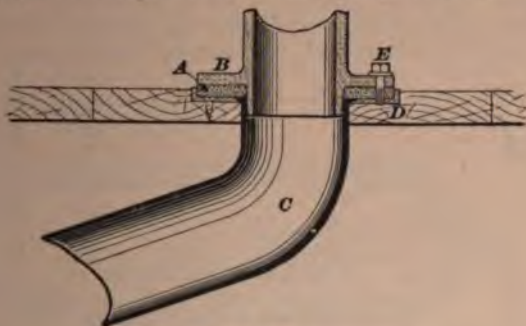


FIG. 289.

upon it by three or four screws or bolts, which should be of substantial size, and be provided with washers, as at *E*.

Sometimes the lead pipe is flanged over on the floor and the porcelain flange is set upon it with a bedding of putty. Such a joint will not remain gas-tight; it is worthless, and should not be allowed.

The porcelain flange has but little strength and is easily broken; therefore, great care should be taken, in screwing up the joint, to avoid breakage.

The best plan is to have only the bowl made of porcelain, and to have the trap made of iron, porcelain-lined, or other metal; this can then be calked into the hub of the soil pipe, and a secure joint made.

The joint between porcelain and metal, which every porcelain fixture must have, should be on the house side of the seal of the trap.

Joints between metal and porcelain are weak and unreliable, and should not be subjected to sewer gas.

910. Fig. 290 shows in plan at (*a*) and section at (*b*) a strong and secure method of **setting a porcelain water-closet upon a marble slab**.

The top of the lead bend *a* is soldered to a brass floor flange, as in the figure. The closet is then set temporarily and the holes are marked on the marble, for the expansion bolts *c*, *c*, etc., which are located at each corner of the closet base, as shown in plan. The closet is then removed, and the four bolt holes are drilled in the marble. The expansion bolts are next secured in position, and the closet is then set permanently,

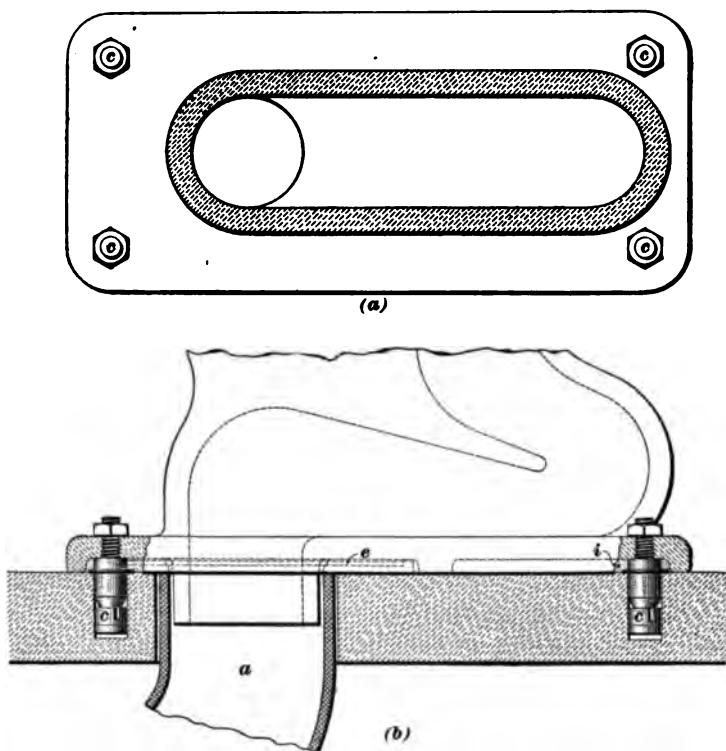


FIG. 200.

a soft rubber gasket being employed, as shown at *e*, to make the joint gas-tight, and plaster of Paris, or, better still, Keene's cement, being used to fill the space *i*, and thereby cement the base solid to the marble. If a porcelain closet is set in this manner, there will be no danger of the gasket

joint leaking by the closet being jarred, or of back-vent horns being broken from the same cause.

911. The **flush-pipe connection**, that is, the connection between the *inlet horn* and the flushing pipe, is commonly made by a screw coupling, as shown in Fig. 291.

The brass nipple *A* is usually put in place before the

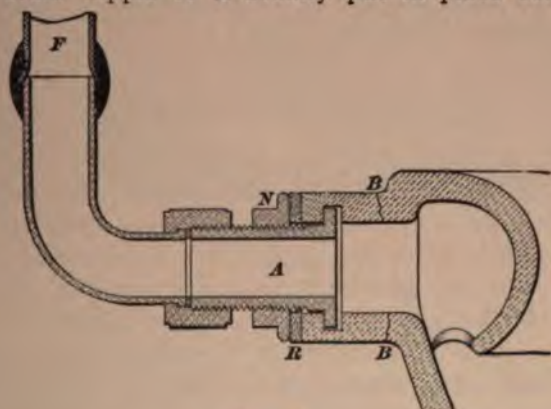


FIG. 291.

porcelain is baked, and it becomes loose during the baking process. To tighten it a locknut *N* and a rubber gasket *R* are used as shown.

This joint is rigid. If the flush pipe *F* is rigidly attached to the walls, and there is any settlement of the building after the attachment to the closet is made, or if the closet is jarred much, a great strain is brought upon the coupling, which frequently breaks off the horn at *B B*.

912. Another way to make the connection is shown in Fig. 292. A **rubber collar** *A* is molded to fit the outside of the horn and

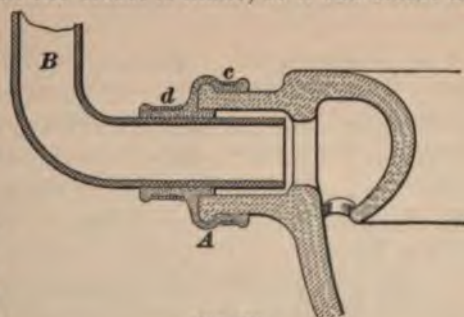


FIG. 292.

the flush pipe *B*. It is secured to both by winding with copper wire at *c* and *d*. If the rubber be of good quality, this joint will be durable and will accommodate itself to any ordinary settlement of the building or jarring of the fixture.

Should there be danger of an extraordinary settlement, the flush pipe *B* should be connected to the horn by a **rubber elbow** or bend.

FLUSHING APPARATUS.

913. The purpose of a flushing apparatus is to thoroughly detach and remove all excreta, etc., from a water-closet bowl and drive it through and beyond the trap. If the excreta can be driven out of the water-closet branch into the main soil pipe or main drain, it should be done, provided the water is abundant and not expensive; but it should invariably be driven out of the trap. A small stream of water, as from a half-inch pipe, although it have a high pressure and be spread out by means of a **fan** or deflector, will not clean the bowl and remove solids from the bowl and trap as well as a similar volume of water which is delivered with a rush through 1½-inch pipe, and is spread out by means of a flushing rim. The small stream of water will frequently fail to make the solid matter, paper, etc., dive under the lip or bend of the trap, but the larger stream causes a rush of water which drives it through very effectively.

The efficiency of a flushing apparatus can be readily tested by coloring the water in the closet bowl with ink and throwing in some pieces of crumpled paper. Then start the apparatus. The flush may be considered satisfactory if no trace of ink or paper remains in the bowl, and if the trap and basin contain a proper quantity of clean water after the flush is over.

To secure a proper flush, a flushing tank should contain from four to six gallons of water, and it should be elevated at least six feet above the water-closet bowl.

914. A common variety of **flushing tank** is shown in Fig. 293. The valve *A* is pulled open by means of the

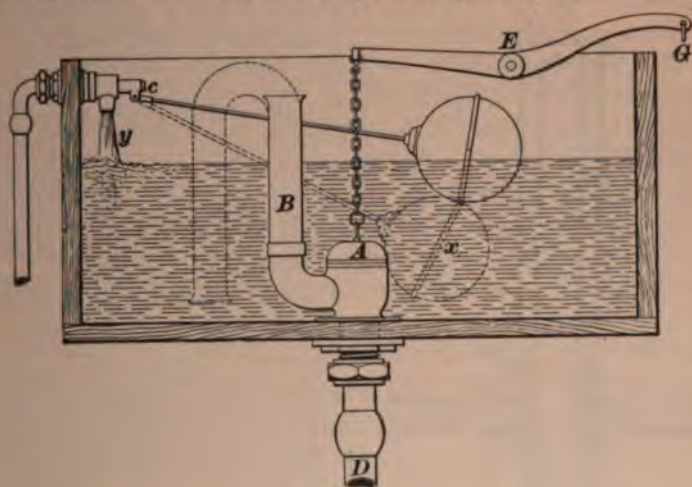


FIG. 293.

lever *E* and hand chain *G*. The overflow *B* opens into the flush pipe *D* beneath the seat of the valve. The water rushes down the flush pipe only while the valve *A* is held open.

The amount of water sent down may be too little to do the work properly, or the water may be wasted by holding the valve open longer than is necessary. The former trouble is most likely to occur, because very few people consider the amount of water which should be delivered in a flush when they pull the chain.

915. To remedy this defect, the **siphon tank** is used. The construction of a **siphon valve** is shown in Fig. 294. It consists of an inner tube *B* and outer tube *C* which are united at the top by an air-tight cap *D*. The inner tube is provided with a rubber ring *R*, which forms the valve, and is seated upon the seat ring *S*. The two tubes thus form a siphon, the inner tube being the long leg. It is started into operation by lifting the valve off its seat. The water rushes down the flush pipe and draws the air

out of *B* and quickly fills both *B* and *C* with water. The valve is dropped back to its seat, and the discharge continues through *B* and *C* until the level of the water falls below the lower end of *C*. Thus, if the valve be opened only a moment, or long enough to start the siphon, the tank will empty to the same point, and the same amount of water will be delivered upon every occasion.

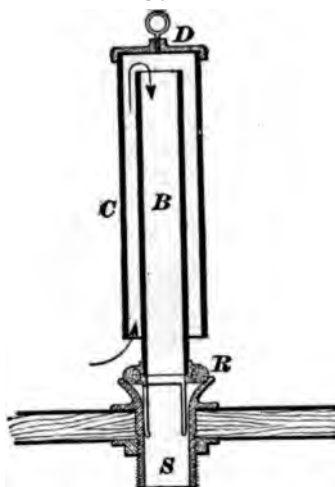


FIG. 294.

The device shown in Fig. 293 can be easily modified to accomplish the same result. The overflow pipe *B* may be prolonged and bent over, as shown by the dotted lines, thus forming a siphon.

916. Another variety of flush tank, known as a **service-box tank**, is employed either to furnish a large flush first and

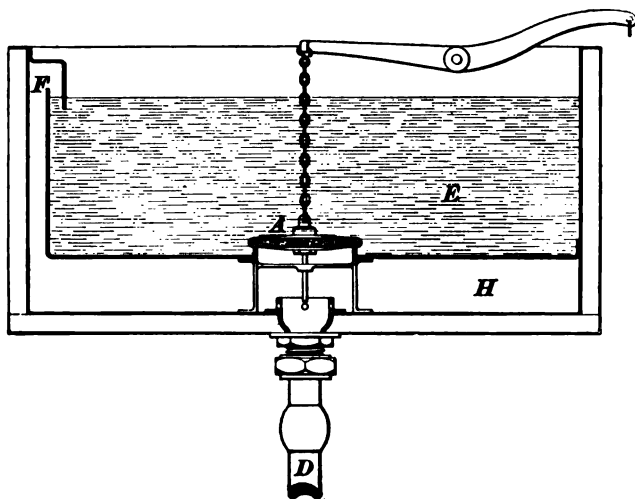


FIG. 295.

a smaller one immediately after, or in some other way to allow a certain volume of water to fall into the bowl and thereby refill same after the tank valve is closed. A service-box tank, or, as some people call it, an *after-flush tank*, is shown in Fig. 295. The tank is divided into upper and lower chambers *E* and *H*. The valve *A* is made about 4 inches in diameter, and when it is opened it passes water much faster than the flush pipe *D* can discharge it. The surplus fills the chamber, or service box, *H*. When *A* is closed the large flush ceases and the lighter flow continues until the chamber *H* is emptied. *F* is the overflow for the chamber *E*.

917. The flushing apparatus may be combined with the water-closet bowl and trap, in one structure, as shown in Figs. 285 and 296. The latter is a section through the plunger valve, at right angles to the view given in Fig. 285, and it shows a ball-cock *K*, which is controlled by the float *H*. The water rises to the same height in the chamber *R* that it does in the bowl *A*, and the float is adjusted to maintain the water at the proper level.

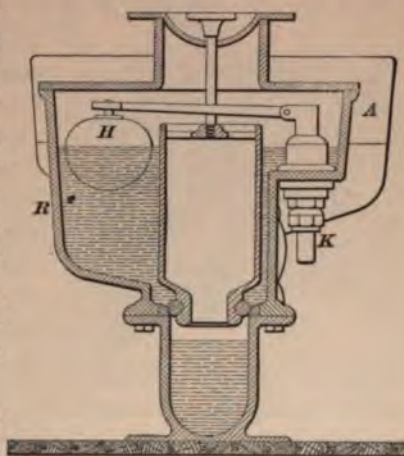


FIG. 296.

Flushing tanks may be dispensed with in some cases, by using a **closet valve** upon the service pipe, which, when opened, will remain open for a short period of time, and will automatically close itself, after permitting a quantity of water to pass which is sufficient to properly flush the bowl.

A valve designed for this purpose is shown in Fig. 297. It is particularly adapted to closets of the plunger principle.

The valve *A* is held up to its seat by the spring *S*. The supply water enters the space between the valve and the

piston *B*. The valve spindle is loose in the valve, and has a conical head at *H* which fits in a corresponding seat in the piston *B*. A small hole *C* permits the water to pass slowly to the under side of the piston. When the valve stem is pushed down by the hand lever *L* the valve *H* opens and allows the water in the lower chamber to escape through the central hole into the outlet *D*. The area of the piston being larger than that of the valve *A*, the water pressure drives the piston downwards until it is arrested by the valve *H*. The pressure upon the opposite sides of the piston being now balanced and the lever being released, the spring *S* pushes the piston upwards and gradually closes the valve *A*. This upward

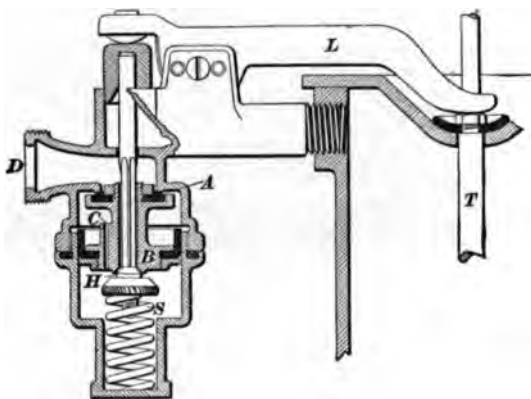


FIG. 297.

motion is gradual because the water required to fill the lower chamber must pass through the small hole *C*, and the spring is not strong enough to drive the piston upwards so rapidly as to form a vacuum behind it. The waterways in this valve should equal the area of 1-inch or $1\frac{1}{4}$ -inch pipe for water-closet service. The end of the lever usually engages with the plunger rod *T* of the closet. These valves are not reliable, as they are too apt to get out of order.

Closets located in exposed places, such as long hoppers in back yards, are supplied with water through an automatic self-closing valve similar to that shown in Fig. 297. The valve is placed below frost, and a small hole is made in the

valve outlet to drain the pipe which connects the valve to the closet horn.

Flushing tanks for water-closets and urinals are commonly made of wood and are lined with copper. They are also made of cast iron, and should be porcelain-lined, enameled, or galvanized, to prevent rusting. Paint is not a sufficient protection for the inside of a tank.

If it *can be avoided*, water-closets should never be supplied with water direct from city mains. Unless exposed to frost, they should in all cases be flushed by small overhead tank arrangements, as the waste of water is thus greatly reduced.

918. Periodical Flushing Tank.—This apparatus is designed for automatically flushing urinals, etc., at regular intervals. The form shown in Fig. 298 is called a **tilting tank**. A tank *A* is divided by a partition into two equal chambers. It rocks upon an axle *B*, and thus brings either chamber under the supply cock *C*. As the chamber fills, the center of gravity of the tilting tank *A* gradually changes until it passes over the axle *B*, when the tank tilts over, emptying one chamber and bringing the other into position for filling. The water being emptied suddenly, a rapid flow is produced, which is well suited for flushing purposes.

The bottom of the outer tank or receiver *D* should preferably be round, that the water may flow more rapidly and more steadily down the outlet pipe *E*. Sheet-metal shields *F* prevent water from splashing over the sides when the tilting tank *A* is discharged. When a number of urinals or closets are to be flushed from the same tank, it should be deep enough to contain the desired quantity of water, and

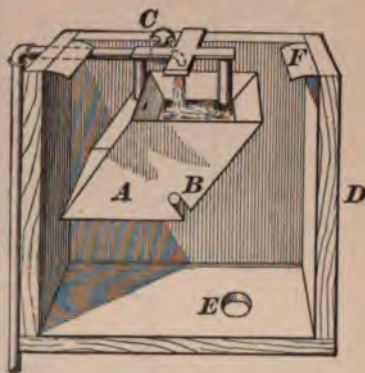


FIG. 298.

the flush pipe opening *E* provided with a siphon which can be started automatically when enough water is emptied into *D*.

919. The flushing apparatus is generally operated by means of a chain or lever pulled by hand. It can also be operated automatically by connecting it to a hinged seat or platform which sustains the weight of the person using the closet. The seat is counterbalanced by means of a spring or a weight which holds it up off its bearings. When the occupant sits upon the seat, it yields an inch or so, and by means of suitable connections to the chain *A*, Fig. 299, it

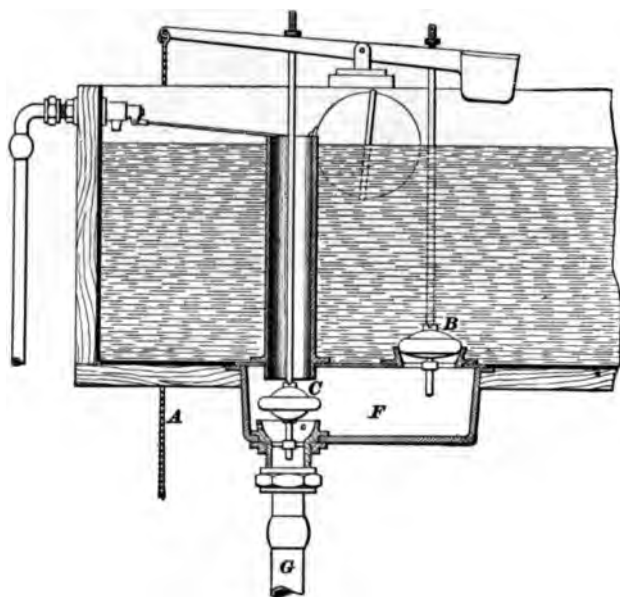


FIG. 299.

opens a valve *B* and closes the valve *C*. This fills the service box *F* with water from the tank. When the person rises, the seat also rises, thus closing the supply valve *B* and opening the discharge valve *C*, when the entire contents of the flushing chamber *F* are quickly sent down the flush pipe *G*. This device is frequently used in railroad stations and

other places where people are liable to go away and neglect flushing the closets. They are especially suitable where a number of closets arranged side by side are flushed from one long storage tank. Each separate flush box *F* should contain about $2\frac{1}{2}$ gallons of water when used with porcelain bowls.

When the water-closet space is enclosed by a door an attachment may be made to the door, which will operate the flushing apparatus every time that the door is opened.

LATRINES.

920. Latrines are a series of strong stoneware or cast-iron pans or closet bowls, usually porcelain-lined, connected at their bottom by a large pipe which forms part of them and which has a gentle fall to the outlet end, as shown in Fig. 300. The bowls *a*, *a*, etc., are furnished with flushing

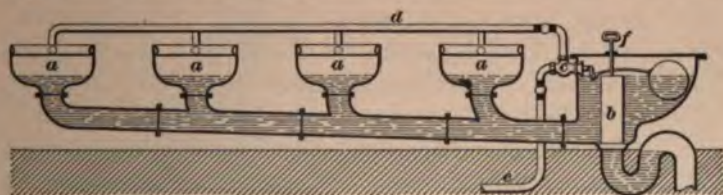


FIG. 300.

rim. A plunger *b*, which also acts as an overflow, is seated water-tight in the plunger chamber. There are many different ways of flushing the bowls. The one shown is similar in principle to the method of flushing the plunger closet in Fig. 296. The valve *c* is opened or closed by the ball float falling or rising with the water in the plunger chamber, which, of course, corresponds with the water-line of the closet bowls. The branches which connect to the flushing rims of the bowls are smaller than the main flush pipe *d*. Latrines are not very desirable fixtures. In this particular style, the entire row must be flushed in order to cleanse any one bowl. A more sanitary arrangement can be obtained by simply using individual closets separately trapped and

flushed from separate tanks overhead. Probably the greatest objection to the latrine shown here is that, should a partial vacuum be formed in the supply pipe *c*, foul air in the closet bowls may be sucked into *c* when the plunger *b* is raised, and thereby contaminate the water supply to other outlets. If the latrines are arranged to be flushed from a large tank overhead, this danger will be overcome.

Latrines are used chiefly in public places, schools, railroad stations, factories, barracks, etc., and they are usually under the control of a janitor.

TROUGH CLOSETS.

921. Trough closets, often called **school closets**, are essentially composed of a long closet seat with a series of holes in it, having a suitable partition between each, and a cast-iron, brick, or earthenware trough under the seats, which should contain water for the excreta to fall into. The bottom of the trough should be round, and should grade down to the outlet, which may have a plunger valve attached, as for the latrines. They are cleaned in a manner similar to latrines. The whole of the internal surface should be flushed by a perforated tube running all around its top, and the solid matter in the bottom should be forced towards the outlet by a large and rapid discharge of water from a jet in the upper end.

When trough closets are flushed from automatic tanks, the plunger valve is omitted, and water to a depth of about 2 inches only is permitted to remain in the bottom of the trough by the aid of an inclined lip near its point of outlet, similar to the lip which retains water in the ordinary washout water-closet.

When such closets are supplied with an abundant and rapid automatic flush, they do good work and require little attention.

Trough closets, like latrines, are commonly employed for use in school-houses, and should be local vented, or the closet apartment should be thoroughly ventilated.

URINALS.

922. Urinals are made of two styles, *round* and *lipped*. The latter are to be preferred, because they catch drippings better than the round ones do.

Urinal waste pipes are much inclined to become choked

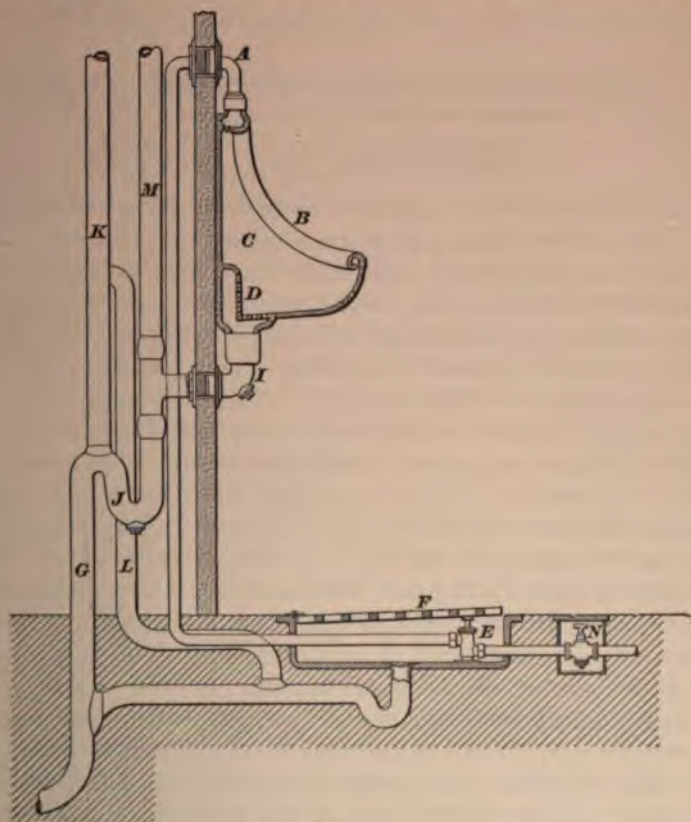


FIG. 301.

from organic matter which is deposited by the urine passing through them; and to flush them properly a considerable quantity of water is necessary.

The flush pipe is usually connected at the top of the urinal, as shown at *A* in Fig. 301. The flushing rim *B* of

the urinal *C* distributes the water so that the whole interior surface is washed.

Urinals which have a strainer over the outlet should be provided with an overflow as at *D*. It is very difficult to prevent urinals from emitting offensive odors, unless they are provided with a local vent of sufficient size to draw a continuous current of air down through the outlet of the bowl.

If water is so scarce that a continuous flush can not be permitted, a **treadle urinal** having an automatic arrangement similar to that shown in Fig. 301 may be used. The supply valve *E* is of the self-closing variety, and the valve stem projects upwards against a hinged platform or treadle *F*. To use the urinal, a person must stand upon the treadle, which yields under his weight sufficiently to open the valve. The water flows as long as the treadle is depressed, and ceases as soon as the weight is removed from it. A small part of the water is used to flush the treadle box and remove the drippings that may fall into it. The waste pipes *G* and *I* and trap *J* should be not less than $1\frac{1}{2}$ inches in diameter. The waste and trap from treadle box should be at least $1\frac{1}{4}$ inches in diameter. The waste pipe from the treadle box should be vented by a $1\frac{1}{4}$ or $1\frac{1}{2}$ -inch pipe *L*, which should join the principal vent pipe *K*. The diameter of *K* should be not less than $1\frac{1}{2}$ inches. The local vent or ventilating pipe *M* should be 2 inches in diameter, and care must be taken to get a good draft of air through it. The stop-cock *N* is used to shut off the water supply.

Attachments which open the supply valve and allow the water to run are sometimes fastened to the door of the stall in which the urinal is enclosed, so that a given quantity of water will be discharged into the urinal every time the door is opened. Consequently, the urinal will be flushed before and after use. The door is closed by a spring or weight.

923. Folding urinals made of iron or porcelain, operating in a manner similar to the folding wash-basin

shown in Fig. 268, are sometimes used. They are flushed by a cock being opened with the cover of the urinal. The cock is shut when the cover is raised and closed. This apparatus is usually set in a recess of the wall, and is provided with a local vent pipe attached, as it is often fitted up in rooms where the least smell would be disagreeable, such as doctors' offices.

HOUSE DRAINS AND DRAINAGE.

SEWAGE AND SEWER GAS.

924. Sewage is composed of water mixed with kitchen slops, grease, soap, urine, washings from stables and slaughter-houses, rags, leaves, paper, human excreta, etc. The animal and vegetable matters in it rapidly decompose and generate noxious gases, and the combination of these is called **sewer gas**. These gases are poisonous, and will inevitably produce sickness if they escape into a dwelling, or if they are breathed in any considerable quantity by those who have weak constitutions or who are susceptible to disease.

An exceedingly dangerous feature of the air contained in sewers is that it is liable to be loaded with putrefactive germs, which will develop typhoid fever, scarlet fever, and diphtheria, if they find a lodgment in the human breath or food.

A small leak of sewer gas into a house may cause much sickness that will probably be ascribed to other causes. Many people will endure a small amount of bad odor rather than incur the expense of sending for a plumber, and are unwilling to believe that a small defect in the drainage can do so much mischief. But the plumber must protect people against their own ignorance and cupidity in this matter.

It is clear, from the nature of sewer gas, that traps and vents upon the drains are not luxuries, but are absolutely necessary to the health of the community.

TRAPS.

925. A **trap** is a device which allows the free passage through it of liquids and such solid matter as the liquid may carry with it, but which prevents the passage of air or gas in either direction.

The simplest form of trap is shown in Fig. 302 and is called a **running trap**. It consists of a downward loop in

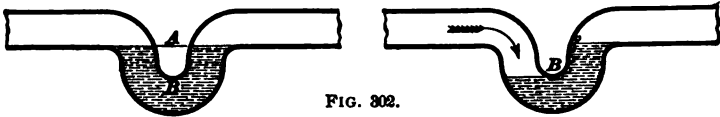


FIG. 302.

a horizontal pipe. The loop is filled with water while the pipe at each side of it may be empty. Whenever water is run through the pipe, enough will be retained to fill the bend, as shown by the drawing to the left, and prevent air or gas at atmospheric pressure from passing. If the air has sufficient pressure it may force the water down upon one side of the bend and up upon the other until the air can escape past the bend at *B*, and bubble upwards through the water, as shown by the drawing to the right. The difference between the level of the water when quiet, as at *A*, and the point *B*, is called the **seal of the trap**, and in no case should this distance ever be less than $1\frac{1}{2}$ inches.

A trap may be made on the principle shown by Fig. 303, in which the end of the discharge pipe is submerged in water. To drive air or gas through this trap enough pressure must be applied to depress the water below the end of the tube.

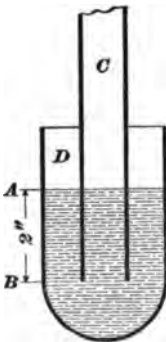


FIG. 303.

It should be noted that a much higher pressure will be required to force gas from the cup back up the tube than in the other direction. The cup is of larger diameter than the tube, and contains a larger volume of water.

For example, the area of the tube is 1 square inch, and that of the cup is 4 square inches, and the height *A B*, or the seal, is

2 inches. To blow air down the tube and through the trap would require a pressure sufficient to depress the water 2 inches in the tube *C*. But as the water falls in *C* it must rise in *D*. Two cubic inches of water forced out of *C* will raise the level $\frac{2}{3}$ of an inch in *D*; consequently, the passage of the air is resisted by a water column $2\frac{2}{3}$ inches high.

Now, to force air in the opposite direction, or backwards, the water in *D* must be depressed 2 inches, or 6 cubic inches of water must be driven into the tube *C*. This, together with the 2 inches already there, will fill the tube to a height of 8 inches. Thus, the passage of the air backwards is resisted by a water column 8 inches high, or three times as much as in the forward direction.

926. Nearly all varieties of traps are modifications of these two. Fig. 302 exhibits the principle of the class called *round pipe*, or *Du Bois* traps, and Fig. 303 that of the class called *bottle*, or *pot traps*. The usual forms of **round pipe traps** are shown in Fig. 304.

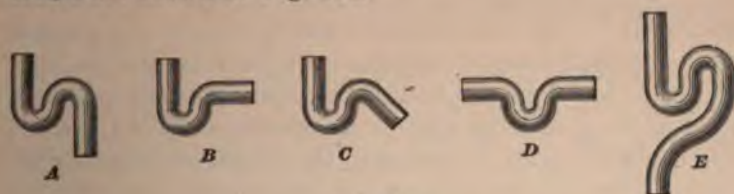


FIG. 304.

A is known as an **S trap**. It is used chiefly under fixtures where the waste pipe descends to the floor.

B is a half **S** or **P trap**. It is used chiefly to join fixtures to a horizontal waste-pipe branch.

C is a $\frac{3}{4}$ **S trap**. It is used chiefly to join fixtures to a **Y** branch in a soil pipe where the distance between the trap and the branch is short.

D is a *lying*, or *running trap*. It can only be used on a horizontal waste pipe. It is often used as a bath trap, being placed under the floor.

E is a *hunchback trap*. This form is used on a vertical pipe where it is desired to have the inlet and outlet in the

same straight line. It is not used as much in plumbing as the other forms.

927. In Fig. 305 is shown a **bottle trap**. These traps are only used under fixtures, such as sinks, baths, basins, or wash-tubs, never under water-closets.

The inlet pipe *A* is attached to the fixture and the outlet pipe *B* joins the waste pipe *D*, of which the part *C* forms the

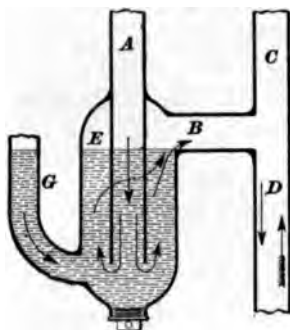


FIG. 305.

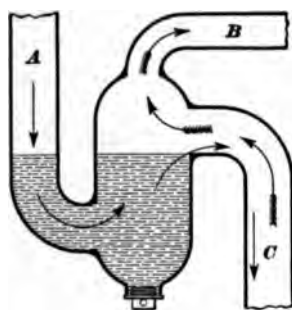


FIG. 306.

back-vent. It is next to impossible to unseal this form of trap, although some of the seal may be lost by siphonage. Its chief objections are that filth is liable to accumulate in the bottom of the trap and grease upon the top of the water and in the chamber *E*, and that the water can not be completely renewed every time the fixture is used. Such a trap, consequently, is not always "self-cleansing."

In Fig. 306 is shown a modification of Fig. 305. It is more direct in action than Fig. 305, and is more easily unsealed. It, however, overcomes the danger of drain air entering the building through unseen holes in its interior, as would occur if the tube *A* in Fig. 305 were corroded within the chamber *E*. Care must be taken when attaching an overflow pipe, for instance, from a wash-basin, to any form of a trap, particularly to those of the pot or bottle formation, to have the overflow pipe properly sealed. An overflow *G* is attached to the body of the trap in Fig. 305.

In Fig. 306 the trap receives waste water from the fixture by the pipe *A*. *B* is the back-vent pipe and *C* the waste

pipe. The arrows with feathers show the direction of the natural air currents in the drainage system.

928. In Fig. 307 is shown a **ball trap**, in which a trap is combined with a check-valve. The ball valve *c* prevents the return of either liquid or gas, and the liquid around the ball keeps the seat gas-tight.

The specific gravity of the ball is but slightly greater than that of water, so that a very slight head of water in *B* will raise

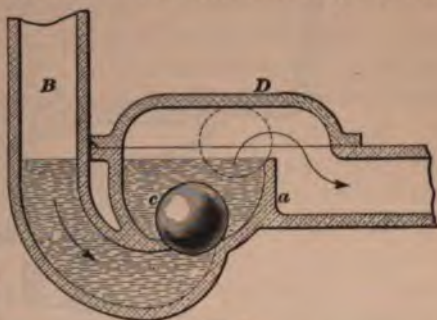


FIG. 307.

the ball. This trap is particularly suitable for clean water fixtures, such as basins or baths, which are liable to remain unused a sufficient length of time to permit the water in the trap to become evaporated and its seal consequently lost.

In such a case the ball will form a nearly gas-tight joint with its seat and prevent the passage of drain air to the building. This and all other traps having the waterway restricted by mechanical appliance, such as check-valves, are liable to chokage by accumulating hair, small pieces of rags, sponges, and even matches.

The position of the ball when water passes through the trap is shown by dotted lines. The ball can not enter the trap outlet pipe, as the space between the lip *a* and the handhole cover *D* is too small.

929. A **bell trap** is shown in Fig. 308. In it the seal is formed by the bell *a*, which is suspended from the strainer *b*, dipping into a small pool of water formed by the waste outlet *c* projecting into the trap casting. The chief objections to the bell trap are:

1. It soon becomes choked by sediment lodging in the bottom which can not be removed without lifting off the

bell. This, for the time being, permits open communication between the drains and the building.

2. It is easily siphoned.

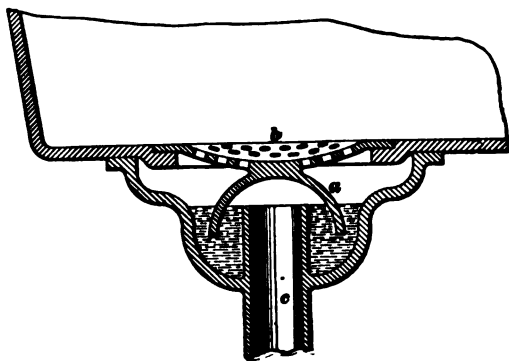


FIG. 308.

3. It is quickly evaporated if not used.

In fact, the bell trap has no redeeming features, and should be abolished in house-drainage systems.

930. General Remarks.—The *requirements of a good trap* are: (1) that it shall entirely and effectually prevent the passage of any air or gas from the waste pipe backwards into the house; (2) that it shall be so constructed that it can be readily cleaned; (3) it should clean itself on all ordinary occasions.

Round pipe traps are usually of the same diameter throughout, and they freely pass nearly everything that can get into them, but they are very liable to become useless through the removal of the water which seals them, by siphonage or evaporation.

The *bottle trap* can seldom be emptied or its security impaired by siphonage, and as it contains a large volume of water, it will withstand evaporation for a longer time than other traps. It will clog easier than a round pipe trap, but is quite as easily cleaned by removing the screw plug which is provided for that purpose. The same depth of seal forms a more effectual barrier against the backflow of gas in a bottle trap than in a round pipe trap, as before explained.

The *ball trap* can not be easily emptied by siphonage, because of the bottle or pot form of construction. When the water evaporates from it, the slime which coats the interior of the trap will cement the ball to its seat, and make a joint that will be gas-tight for a long time, provided that the seat be free from shreds of cloth, hair, etc. The usefulness of the ball is very apt to be destroyed by refuse of that kind. In that case it is worse than an ordinary trap.

A *trap for outdoor service*, to receive surface water from courts, areas, roofs, etc., should have a deep seal, from 8 inches to 1 foot, according to the warmth and length of the dry seasons.

Check-valves should not be used in place of traps, because they are very liable to be prevented from closing properly by the lodgment of refuse, such as strings, rags, paper, etc., between the valve and its seat.

All traps should have a cleaning hole. The screw plug or *trap screw* which is used to close the hole should be of such shape and size that a wrench can be applied to it firmly and safely. Large traps, such as used for drains, should have a 4-inch (or larger) *handhole* and a suitable cover. These plugs or covers must always be made both water- and gas-tight by means of screwed joints.

A *separate trap* should be placed under each bath-tub, wash-basin, sink, water-closet, or urinal, and one trap should be attached to each set of laundry tubs. Traps should be set as close to the fixtures as possible.

A *main disconnecting trap* should be placed in each main drain so as to disconnect the house pipes from the sewer.

No trap should be placed at any point where it will check the free circulation of air through the drainage system.

A check-valve may be used on a drain, between the main disconnecting trap and the sewer, to protect the house drains from any back flow from the sewer. When the drain pipe empties into a river or into the sea below high-water mark, it should be protected by attaching a valve of this kind.

931. *Double trapping* is an arrangement of two traps in immediate succession, so that the wastes must flow through both. This arrangement should always be carefully avoided, because the refuse is apt to lodge in the second trap and choke it. A certain amount of head or hydraulic pressure is required to drive the waste water through one trap, and if two traps are to be passed, twice that amount of head will be required. If two traps placed upon a drainage system confine the air between them, an air lock will take place, the evil effects of which have already been explained.

This matter should be carefully examined into, especially when making additions to or repairing old work.

932. Refrigerators should have a trap on the waste pipe. The object of the trap is to allow the waste water to pass out, and to prevent the cold air from escaping also. The cold air is heavier than the air at ordinary temperatures, and it settles at the bottom of the chamber. If there is any hole open, the cold air will flow out very much as water would, and the result is a waste of ice. The trap also prevents the entrance of bad air or dust. Cooling rooms for butter and cold storage must be carefully guarded in this respect.

Ample facilities for cleaning the traps must always be provided, because they frequently choke with the sawdust which accompanies the ice.

The waste pipe should not be directly connected to a drain or sewer pipe, but should discharge into some clean place where it can be seen and where there is no bad air. The utmost cleanliness must be preserved at all points about refrigerators or cold-storage rooms.

In apartment or flatted buildings, it is customary for the plumber to run a vertical line of 2-inch or 1½-inch galvanized iron pipe from cellar up to and through the roof, having 1¼" or 1½" branches taken off at each floor to receive the water from the ice-boxes or refrigerators. The lower end of the vertical pipe line usually delivers openly, over and

into a water-supplied sink. The branches to the refrigerator safes, if any be used, are all trapped just under the safe strainer.

933. Rain-water leaders, if connected to the drains, must be provided with traps having a seal so deep that the water in them will not evaporate sufficiently to unseal them during long spells of dry weather. These traps must be secured against frost. They are usually placed in the cellars. Such traps should always be accessible, because they are very liable to chokage.

GREASE INTERCEPTERS AND TRAPS.

934. Grease is very troublesome, because it is liquid and runs out of the sink readily while accompanied by hot water; but as soon as it encounters the cold surface of the waste or drain pipe, it solidifies and adheres to the pipe. The caliber of the pipe is thus reduced, and it will eventually be choked by the grease; consequently, it often happens that some contrivance must be employed to prevent the grease from entering the drainage system.

An ordinary variety of **grease interceptor and trap** combined is shown in Fig. 309. *C* is the waste pipe from the sink, *B* is the pipe leading to the drain, and *A* is a fresh-air inlet. The cover *D* should be large enough to readily permit the inside of the trap to be cleaned, and should be secured in position.

The grease having a density less than that of water, accumulates in a layer at *G*, and if allowed to become cold will solidify into a cake which can easily be removed.

This form of grease trap is mostly used for intercepting grease from kitchen sinks in large country buildings. As the trap must be large in order to prevent the grease from

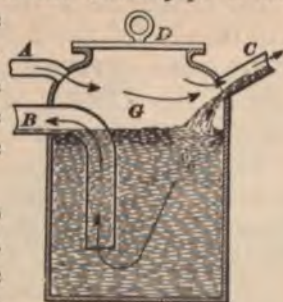


FIG. 309.

entering the outlet *B*, it is usually placed underground as near the sink as possible.

935. A superior variety known as a **chilling trap** is shown in Fig. 310. *B* is the waste pipe from the sink and *D* is the pipe leading to the drain. *F* is the vent pipe and *K* is a local vent or air relief pipe. The contents of the trap are chilled by means of a jacket *A* through which cold water is made to circulate. Commonly, the cold water supply to the kitchen boiler is used for this purpose, the water entering the trap through *H* and passing to the boiler

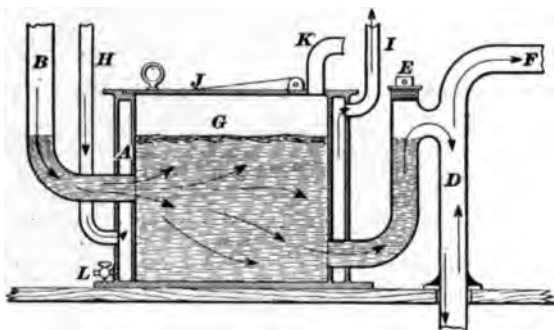


FIG. 310.

through *I*. *J* is a close-fitting hinged cover. The grease chills into a cake at *G* and is removed by opening the cover.

The separation of the grease will be more perfect in this trap than in the one shown in Fig. 309, because the layer of grease is not disturbed by the water in entering nor in leaving the trap. In Fig. 309 the entering water passes through the layer of grease and is liable to carry some of it along over into the waste pipe. A trap screw *E* is attached for access to the trap outlet. A pet-cock *L* is screwed into the water-jacket to drain it when required.

MAIN DISCONNECTING TRAPS.

936. The main disconnecting trap, or **main drain trap**, as it is sometimes called, is a very important item in a house-drainage system. Its duty is to prevent gases in the city sewers or cesspools from entering the house drains

These gases are usually considered to be more dangerous than those generated within a house-drainage system.

There are many different forms of main disconnecting traps on the market, some of which are really very efficient and some are worse than useless.

The requirements of a good main disconnecting trap are:

1. It should, under all conditions and at all times, maintain a perfect disconnection between the gases in the street sewers and those in the house drains.

2. It should, under all ordinary conditions, be self-cleansing, so that solid matter may not accumulate in it and evolve gases.

3. It should, in all cases, be accessible for cleaning-out purposes and for inspection, the handholes being maintained positively gas-tight, preferably by means of screwed joints (metal to metal), not by a bedding of putty.

937. There are two leading reasons for disconnecting the buildings from sewers and cesspools.

First—To have the air in the house-drainage system in as pure a condition as possible, so that, should any leak occur, the dangers connected therewith will be reduced to a minimum.

Second—To maintain as pure an atmosphere over and around the buildings as the circumstances will permit.

In Fig. 311 is shown what used to be a very common method of preventing sewer gases in the fire-clay sewer connection pipe *a* from entering the house-drainage system, of which *b* is the cast-iron main house drain within the cellar, and *c* a cast-iron fresh-air inlet continued to the outer atmosphere.



FIG. 311.

The trap *r* remains constantly full of water, as shown, and thus prevents the passage of gases from *a* to *b*.

938. There are many objections to the arrangement shown in Fig. 311, the principal ones being:

1. Owing to the water-line of the trap being up to the lip *e*, the sewage will be carried, by its own momentum, against the inner surface at *v*, and a head of water will have to be formed in *b* and the trap inlet to force the sewage through the trap and into *a*. This head, combined with eddies, will prevent, to a great extent, solid matter whose specific gravity is less than that of water from passing under the tongue *t* of the trap and into *a*. The trap will, therefore, not always be self-cleansing with ordinary flushes from the fixtures.

2. Should the wall or the earth outside of it settle at any time, the fireclay pipe which runs through the wall and into the cellar would certainly break; in this way sewer gas would be admitted to the cellar.

3. Assuming that no settlement of the wall or earth takes place, and the pipe *a* remains intact, the expansion and contraction of *b*, due to changes in its temperature, would soon loosen the joint between the *tail* of the trap and the fireclay pipe, or crack off the socket.

In Fig. 312, the wall in which the fireclay pipe *a* is solidly bedded with cement has settled, while the earth remained

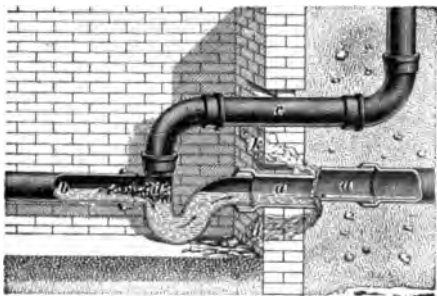


FIG. 312.

unmoved, and the pipe has broken off just outside the cellar wall. The effect of this break is to allow liquid sewage to flow into the cellar, through open joints in the masonry, as at *j*, and sewer gas to enter the cellar in a similar manner, as at *k*;

it also allows solid matter to accumulate at *u*, and in the drain *b* by the sewage backing up there to form a head sufficient to cause a flow through *a*. In order to avoid the

objections specified, the trap may be constructed and fitted up as shown in Fig. 313. Here is shown a trap so constructed that, when set properly, the inlet lip *e* is about 2 to 3 inches above the normal water-line of the trap, so that the liquid sewage, by falling into the trap well, that is, the space just over the water in the inlet side of the trap, will force any solid matter in the well down under the tongue and through the trap, as shown by the arrows.

The space between *e* and the water-line also provides for

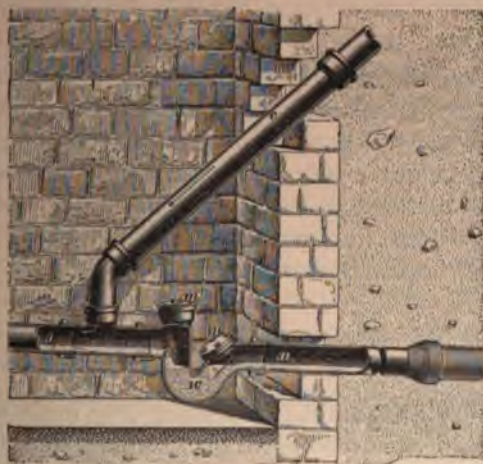


FIG 313.

a small head of water which is required to cause a flow through *a* to the sewer, and by so doing prevents water from backing in the house drain *b*, thus permitting solids carried by the water in *b* to be easily deposited into the trap well, from which they are just as easily forced by the small cascade falling upon them, under the tongue and through the trap *w*.

In order to obtain easy access to *a* and *b*, or to the trap itself, the fresh-air inlet *c* is joined to a T branch, and a 4 or 5-inch brass trap screw, the socket of which forms a sleeve for calking, is secured into the hub of the trap, as at *m*. This gives access to the main house drain and the trap well.

Another handhole, or access plate, is shown at *n*; this is for easy access to the pipe *a*. It is composed of a dead plate secured by bolts to a flange cast on the trap, a pliable gasket being placed between the plate and the flange to form an air-tight joint when the plate is set down tight. It is very essential that this handhole be hermetically sealed, because the pipe *a* will constantly be loaded with sewer gas, and if the plate should not be bedded tight, sewer gas will flow into the cellar unobserved. A screwed cap having metal to metal contact is preferable for closing the handhole *n*.

939. Care should be taken to allow a space all around the pipe where it passes through the wall, particularly over it, so that the wall may settle without touching the pipe. In Fig. 313, the iron sewer connection *a* is continued through the wall to a distance of 5 or 10 feet before it joins the fireclay pipe, so that if any slight leak should occur in the fireclay pipes or their joints, the leakage will not affect the building.

The fireclay sewer pipe should never, on any account, be continued into the cellar as shown in Figs. 311 and 312.

940. When a main disconnecting trap must necessarily be located outside of the building and underground, it is customary to build a brick manhole around it for easy access. If the manhole is remote from windows, doors, etc., it is customary to provide it with a perforated cover so that fresh air may easily enter. In such a case the handhole on the trap inlet is left open and the manhole floor is cemented water-tight and made flush with the handhole.

A manhole should be at least 2 feet 6 inches in diameter at the base, the walls being built of brick and 8 inches thick. It should be closed on top by a flag of pavement at least 3 inches thick, and the iron cover or grating, as the case may be, should be sunk flush into the stone. The opening in the stone should be at least 15 inches in diameter, or square, and the plate which covers it should have a 1-inch bearing all around.

FRESH-AIR CIRCULATION IN DRAINAGE SYSTEMS.

941. All of the drains, soil pipes, and waste pipes which are wholly or partly inside of a dwelling or public building should be kept free from accumulation of foul gases or odors, and should be so freely vented that the water seals can not be sucked out of the traps by siphonage nor blown by back pressure.

The necessity of ventilating all drains, soil, and waste pipes in a building is evident when we consider that no matter how well these pipes are cleansed by flushes of water passing through them, there will always be deposits of solid matter upon their internal surfaces. These deposits decompose and evolve gases which are dangerous to a greater or less extent, according to their composition. In order to convey these gases from the pipe system, and allow them to discharge into the atmosphere, the vertical stacks are continued full size or larger up to and through the roof of the building where they terminate with open ends. A branch, known as the **fresh-air inlet**, taken from the lower part of the house-drainage system, is led to the atmosphere at another point for the purpose of admitting a supply of fresh air to take the place of the foul air that is ejected above the roof.

942. Fig. 314 shows a sectional elevation of a drainage system, and will be sufficient to illustrate the principles of drainage ventilation. The water-closet *A* discharges into the soil-pipe stack *B* through the soil-pipe branch *a*. The bath *C* discharges into *B* through the waste pipe *b*. Drain air is prevented from entering the building by the bath trap *c*, and the water-closet trap which forms part of the closet, and which is molded to it. A main disconnecting trap *D* prevents gases generating within the sewer *E* from flowing through the house-drainage system. The top of the soil-pipe stack *B* and the orifice of the fresh-air inlet pipe *F* are open to the atmosphere; consequently, when the air or gases in the drainage system are lighter than an equal

volume of the outer atmosphere, they will flow up through the system and discharge into the atmosphere above the roof, as shown by the arrows. They are displaced by a volume of fresh air flowing under atmospheric pressure into the system through the pipe *F*. This fresh air mixes with the gases, and, in turn, is soon ejected from the system. The velocity of a current of air flowing through a drainage system will vary considerably with changes in temperature, with the pressure upon the inlet or outlet

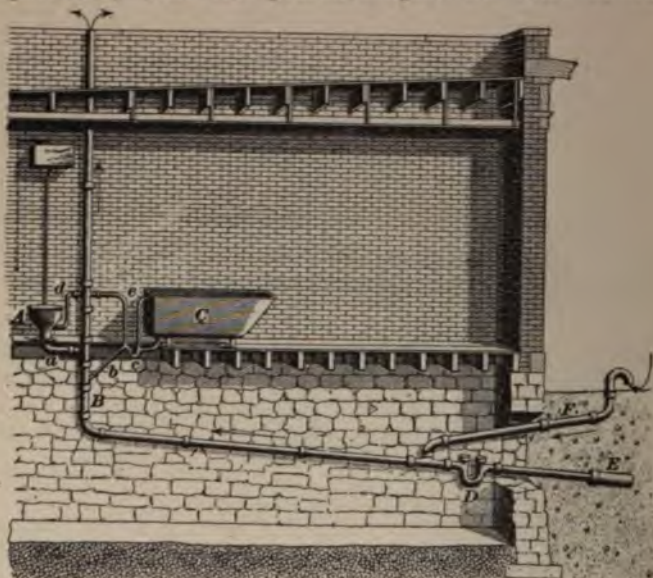


FIG. 314.

orifice, etc. In many cases the currents are reversed; that is, the drain air is forced out of the fresh-air inlet pipe. Such would be the case if the water discharged from the fixtures should form a nearly solid plug while flowing through the pipe. The effect of the flush would be to force the drain air ahead. For this reason great care should be taken in selecting the point of fresh-air inlet. The branch pipes *a* and *b* are ventilated by back-vent pipes *d* and *e*, which join their highest points to the main stack. The

principal use of these, however, is to prevent the siphoning of the traps when water flows through *a* or *b*.

943. The **location of the fresh-air inlet** is a matter of very great importance, and many things must be considered in selecting it. If the current of air which flows through the fresh-air inlet pipe always flowed inwards, the selection of the location of the inlet would not be such an important matter, but there are times when a **blow-back** actually occurs at the inlet orifice, which then becomes a temporary foul-air outlet. In order to prevent the drain air so blown back from being a dangerous nuisance to the inmates of the building, many of the health department laws compel the inlet orifice to be at least 15 feet from any window or door. This, of course, is to prevent blow-backs from entering the building.

Since the main house drains from nearly all city buildings are continued through the front wall and join the street sewer, and the fresh-air inlet pipe is, consequently, run from the main house drain at the front of the building, it stands to reason that if the inlet orifice must be 15 feet or more from the windows, the inlet of fresh air must be taken from a point near the street curb or from a point above the building. It may be done either way, but the former method is usually employed. When taken from the curb, particular care must be exercised to avoid arranging the inlet orifice in such a manner that dirt or street sweepings may at any time enter and choke the pipe, thereby cutting off the flow of fresh air to the system.

A very common method of running the fresh-air inlet is shown in Fig. 315. The inlet pipe *a*, which joins the house side of the main disconnecting trap in the cellar, is connected to a **curb box** *b*, as shown. The

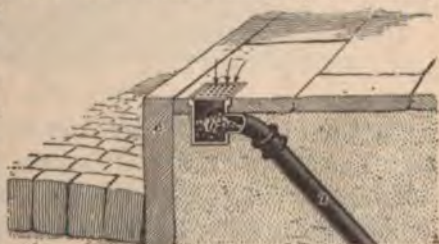


FIG. 315.

top of this box is sunk flush with the sidewalk and is fitted

with a movable grating which can be lifted out or swung over on hinges to facilitate the cleaning of the box.

The chief objection to this method is that the box will gradually fill up with pavement sweepings, as shown, and the air supply will thus be choked off. It is also very much affected by snow storms. Even though the pavement is swept clean after a fall of snow, the perforations of the grating will remain clogged with snow and ice. In fact, this form of fresh-air inlet, if not attended to, becomes practically useless.

To prevent any chokage by dirt, the pipe *a* is sometimes continued through the curbstone *c*, thus opening into the street gutter, and is provided with a grating over its mouth, which is set flush with the face of the stone. While this removes the objection to dirt accumulation, it is usually entirely closed while snow lies in the streets, the gutters being made the receptacles for the snow until it melts or is carted away.

944. In order to have the drainage system efficiently ventilated, it is necessary that the fresh-air inlet be the full size of the main drain, and that its caliber be unobstructed. When a grating is used over the inlet, the perforations should be at least equal in area to the sectional area of the pipe itself. This will reduce the resistance to the inflowing air to the minimum.

There are three general methods by which fresh-air inlets may be made **self-cleansing** :

The first is to arrange the inlet orifice in such a manner that dirt can not possibly enter.

The second is to give the pipe a pitch down to the main house drain greater than the angle of repose for dirt, say a little over 45 degrees. The dirt falling in will then slide down into the house drain and be carried to the sewer by discharges from the house fixtures.

The third is to so arrange the pipes that periodical flushes of clean water will pass down the fresh-air inlet pipe, and so carry away all dirt accumulations. This may be accomplished by discharging area storm water, or roof water, into the inlet pipe above the dirt accumulations.

The first general method may be accomplished by continuing the fresh-air inlet pipe above the ground and protecting its orifice with a hood or cowl. This plan, although perfectly suitable for country buildings and such city buildings as may have a few yards of open ground in front of them, is not adapted to the generality of city work, because in most cases fresh-air inlets must be taken from points where considerable traffic prevails, and they are usually in the way.

Probably the best arrangement that can be employed for the average city building is the **perforated hollow hitching-post** arrangement *A*, or a **perforated hollow stepping-block** arrangement *B*, Fig. 316.



FIG. 316.

It will be seen in this figure that there is no danger of obstructions by dirt or snow to the flow of air through either of these inlets. As the hitching-post and the stepping-block are great conveniences, it seems reasonable to suppose that they should be more generally employed than they are at present, to do the double duty of affording accommodation to carriages and acting as fresh-air inlets.

945. The student will observe in Figs. 311 and 312 that the fresh-air inlet pipe *c* joins the trap, and the fresh air as it enters the system is thereby caused to impinge upon the surface of the water in the trap. This method of connecting the fresh-air inlet has the following disadvantages:

First—The evaporation of the water in the trap is much more rapid than it is when the fresh-air inlet is connected to the house drain at a point near the trap, as shown in Figs. 313 and 314. Of course, the evaporation that takes place in either method of connection is not sufficiently great to decrease the seal of the trap to a dangerous extent when the house is occupied and the drainage system is subject to ordinary use; but if the house is not inhabited for any considerable time, and the plumbing fixtures consequently unused, the evaporation from a trap connected as shown in Figs. 311 and 312 may be sufficiently rapid to entirely unseal the trap, while another trap of the same shape and dimensions, if connected up, as shown in Figs. 313 and 314, and otherwise subject to the same conditions, would probably keep its seal intact.

Second—If the fresh-air current is very cold, which it certainly will be during the winter if the building is situated in the northern part of the United States, heat will be rapidly absorbed from the water in the trap by the cold air impinging upon the liquid. The tendency, then, will be to form a sheet of ice over the water in the inlet side of the trap, which will be equivalent to a temporarily choked drain, and may be the cause of much damage.

This trouble will not be experienced if the plumbing is in nearly constant use, because water flowing into the trap displaces that which is chilled by the current of cold air.

When the fresh-air inlet is connected a few feet from the trap, this danger is avoided because the inlet of the trap is practically a short dead end and the heat of the trap can only be transmitted to that matter surrounding the trap; the current of cold air entering the drainage system does

not affect the temperature of the water in the trap because there is no circulation in the dead end.

Gases generated in this so-called dead end will diffuse with the fresh-air current, and this part of the system will actually be ventilated by diffusion.

946. It will also be noticed that the pipe *c* is run horizontally, or nearly so, in Figs. 311 and 312. This is an exceedingly bad feature in its construction, particularly if its orifice of inlet is flush with the sidewalk, as is often the case in large cities, because dust and other street sweepings are liable to enter the pipe *c* and accumulate in the bend, as shown at *s* in Fig. 311, and thereby partly or entirely stop the flow of fresh air into the drainage system.

To avoid this danger, the fresh-air inlet pipe should (if possible) be run with a pitch upwards to the street grating, as shown in Fig. 313.

VENTS AND SIPHONAGE.

947. The water which seals a trap is very apt to be drawn out by the suction of the water which passes down the waste pipe, unless some means be used to destroy the suction. The waste water should always be driven through the trap by hydraulic pressure, instead of being pulled through, as it were, by suction. Suction can be entirely prevented by attaching an "air," or "vent pipe," as shown at *a* in Fig. 317. The **effect of siphonage** is shown in Fig. 318. The suction will continue until the level of the flowing water falls below the tongue of the trap at *a*, when air will enter and stop the suction. The water between *a* and *c* still has considerable momentum, and some of it will

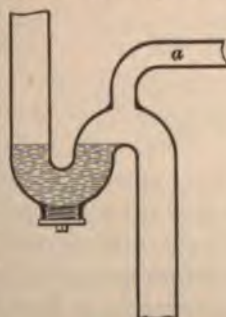


FIG. 317.



FIG. 318.

pass over *c*, but the remainder will fall back into the lower bend. The quantity, however, is too small to fill the bend; consequently, an opening is left which permits the backflow of sewer gas, as shown by the arrow.

948. The **back-vent pipe**, that is to say, the pipe which joins the crown of a trap and leads to the outer atmosphere, either directly or by being connected to a special vent stack, does a double duty. It not only prevents the seal of the fixture trap from becoming siphoned down to a dangerous extent, as shown in Fig. 318, but also acts as a ventilating pipe to remove gases of putrefaction or foul air from the waste-pipe branch to the fixture. If drain air is allowed to accumulate in a branch, or *dead end*, the metal composing such a pipe will soon be corroded through and leaks will thus be formed. Lead especially is very susceptible to drain or sewer gases, and unventilated leaden drain or waste pipes soon become honeycombed with numerous small "pittings;" the lead becomes quite rotten and brittle. When back-vent pipes are properly applied, they not only ensure uniform trap seals; but also prolong the life of the pipes.

949. It sometimes occurs that a certain fixture, such as a wash-basin or set of laundry tubs, is located in such a position that it can not be properly back-vented without enormous expense and annoyance. In such a case the best thing to do is to attach an **anti-siphon** back-vent. This apparatus is simply a light check-valve sealed in mercury. It is connected to the crown of the trap, and the check-valve is so arranged that when the pressure in the crown of the trap becomes much less than that of the atmosphere, the valve will be raised out of the mercury and air will flow in to break the siphonage. The valve will then fall in the mercury and thus become sealed air-tight. Anti-siphon arrangements are not recommended by us because of the many ways by which they may be rendered not only useless, but positively dangerous. For example, the valve may stick or the mercury may be lost or stolen from the cup,

and drain gases would then flow through the valve and into the building. Another objection is the fact that the waste pipe of any fixture which is fitted with an anti-siphon arrangement is really a dead end, and no ventilation is present except a slight displacement of the foul air when the fixture is heavily flushed.

SOIL, WASTE, AND VENT PIPES.

950. Waste pipes are the pipes that convey waste water from any or all the fixtures in a building except the water-closets. If their length exceed 4 or 5 feet they are usually made of cast iron. A general custom in the United States is to make all stacks or vertical lines of pipes of cast iron, with spigot and socket joints, or of wrought iron or steel pipe having screwed joints and flush fittings.

The *branch pipes* through which the fixtures discharge into the stack are made of lead, if short. If more than 5 feet in length, and without too many changes in direction, an iron-pipe branch is generally carried to a point suitable for a lead-pipe connection to the fixture. The reason why lead waste-pipe connections are generally made to the fixtures is because the lead can be bent to suit any position, and forms a pliable connection which will not break the fixture owing to a small settlement of the pipes or building. The pipe should have a good fall towards the *stack* to secure a rapid flow of water. The Y branch of the stack should be located as low down as practicable, and the waste pipe may be run between the floor-beams.

The waste pipes from baths and basins should be directly connected to the soil-pipe stack, and should not be connected to the water-closet branch.

Waste pipes of lead should not be wiped or connected at right angles, but always at a smaller angle which will favor the passage of matter towards the outlet, so that the water which is being discharged from one waste pipe can not back up into some other pipe, because it will form deposits in, and choke up, the other pipe.

The waste pipes from safes should not be connected to a soil or vent stack. They should discharge openly at some conspicuous place where the least indication of a leak will be quickly made apparent.

The waste pipe from a refrigerator should not, under any circumstances, be connected to a soil or vent pipe, but should discharge at some clean place.

The overflow from a house tank or cistern should not be discharged into a drain or soil pipe, but should discharge openly in a place where the overflow will be seen.

Urinal waste pipes should be as short as possible. They should be well supplied with screw caps, to afford easy access to the pipe for cleaning-out purposes, as a thick slime accumulates in such pipes.

951. The proper **sizes of waste pipes** for various uses are as follows :

Bath waste, $1\frac{1}{2}$ " to 2" in diameter.

Basin waste, $1\frac{1}{4}$ " to $1\frac{1}{2}$ " in diameter.

Urinal waste, $1\frac{1}{4}$ " to $1\frac{1}{2}$ " in diameter.

Wash-tubs, $1\frac{1}{2}$ " branch and 2" trap for three tubs, the trap taking one tub.

Sink waste, $1\frac{1}{2}$ " to 2" in diameter.

Pantry-sink waste, $1\frac{1}{2}$ " in diameter.

Safe waste, 1" to $1\frac{1}{2}$ " in diameter.

Water-closet trap, $3\frac{1}{4}$ " to $3\frac{1}{2}$ " in diameter.

Soil-pipe stack, 4" to 5" in diameter.

Branch to closet from soil-pipe stack, 4" in diameter.

Sink and tub stack, 2" to 3" in diameter.

952. Soil and vent pipes should run vertically if practicable, and if they must be run otherwise, they should be inclined not less than 1 foot in 40 feet. All bends and curves should be made of large radius. Where an offset has to be made in a soil or vent pipe, it is advisable to use two **obtuse-angled bends** *B*, *B*, as shown in Fig. 319. Right-angle elbows, as at *A*, should not be used for this purpose.

All branches to waste pipes and connections to the main

drains should be made with **Y branches**, instead of branches at right angles, as shown in Fig. 320.

The **Y branch** *A* should be inclined in the direction of the flow, that is, downwards towards a soil pipe, and upwards towards a vent pipe. By inserting an eighth bend *B* into the **Y branch**, one pipe can be connected to another at right angles in a proper manner.

All soil pipes should extend through and above the roof, thus forming **foul-air outlets**. The diameter of the pipe must be increased

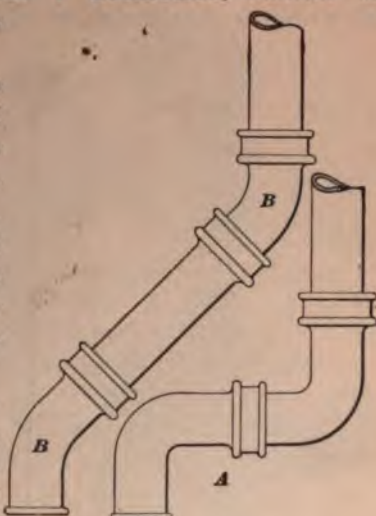


FIG. 319.

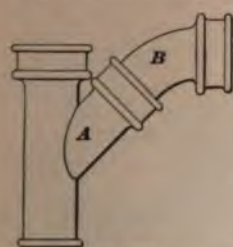


FIG. 320.

before it passes through the roof, because the warm air and vapor which rise in it will be condensed and in cold weather the outdoor end of the pipe will become lined with ice. The formation of ice will continue until the mouth of the pipe may be choked. By enlarging the pipe, the time required to choke it is greatly prolonged.

Thus, a 4-inch stack should be increased to 5 inches diameter at the roof, as shown in Fig. 321. The hub of the 5-inch piece *B* should extend above the roof to the extent shown or slightly lower. The opening through the roof should be made water-tight by means of the flashing *F* of sheet lead. This should be extended upwards under the shingles or slates *A* and be securely nailed to the roof boards. The hole for the pipe *C* should be flanged downwards into the hub of *B*, so that when the joint is calked with oakum and lead, a perfectly water-tight joint will be made with the flashing. Care must be taken, when dressing the sheet lead

into the socket, or when calking the joint, not to cut the sheet lead against the sharp edge of the socket.

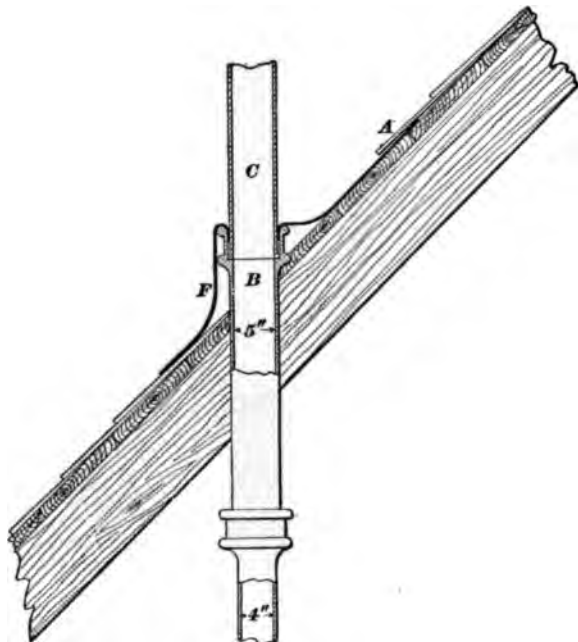


FIG. 321.

953. If a cowl or vent cap of the ordinary pattern is attached to the top of the vent pipe, as shown at *a* in Fig. 322, ice will soon be formed within the cold exposed pipe, as at *b*, of sufficient thickness to entirely close the airway *c*, as shown.

The air passage through this form of a cowl, as it is at present placed upon the market, is altogether too small, being only about one-half or three-fourths of an inch wide, and it soon becomes so choked with ice as to almost entirely, if not quite, stop ventilation. Whether the pipe is fitted with a vent cowl or not, there will be more or less danger of chokage by frost, but the danger is greatest when cowls are used.

In exceedingly cold parts of the country, it is best to avoid

caps or cowls if possible, and use only the straight pipe *a* with an open top, as shown in Fig. 323, and it is well, even then, to protect the exposed pipe with some non-conducting material *b*, such as mineral wool or hair felt protected against rain, snow, and wind by an impervious covering which is shown flanged on to the flat roof, and soldered down, its top being doubled over the hubs and secured watertight by lead and oakum calking.

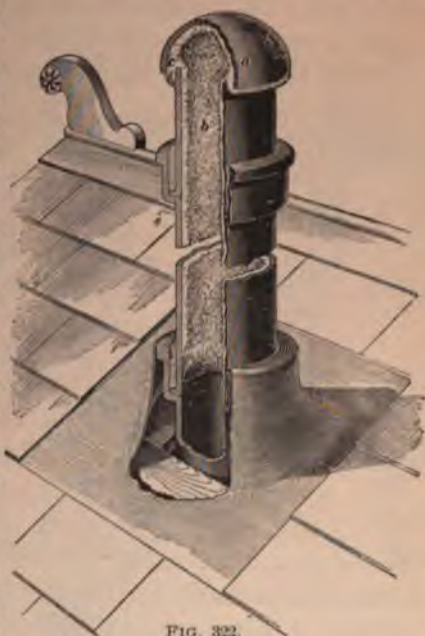


FIG. 322.

954. All branch pipes should be ventilated. This is usually accomplished by attaching a vent pipe to the crown of each

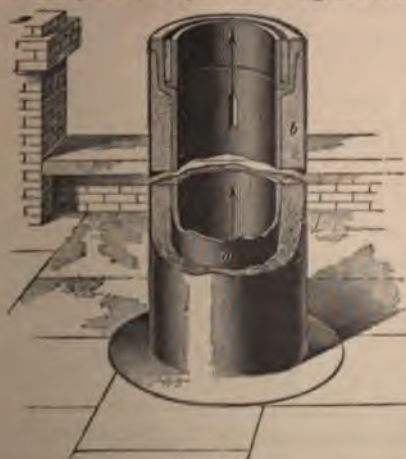


FIG. 323.

trap. It will relieve the pipe from accumulations of foul gas, secure a steady current of fresh air through it, and prevent the sealing water from being sucked out of the traps by siphonage.

The separate vent pipes should be connected to one vent stack unless the horizontal distance to be traveled is so great that a good draft can not be secured.

Local vents must not be connected to the vent stack. Rain-water leaders should not be used for vent pipes. Vent pipes must be connected to that side of the trap which is between the seal and the soil, or drain, pipe.

955. The proper mode of connecting the vent pipe is shown at *A* in Fig. 324. A common but improper vent

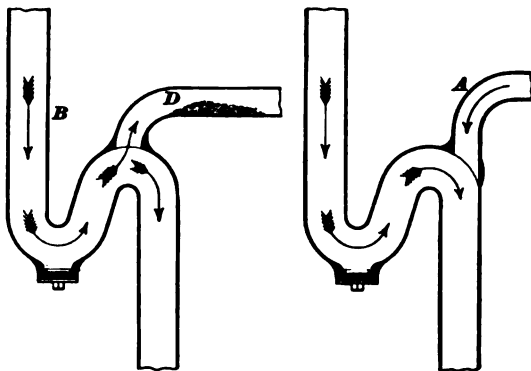


FIG. 324.

connection is shown at *D* in the same figure. When a large volume of water enters the trap suddenly, it will drive up into the part *D*, and if it carries grease, soap, or refuse with it, it will be deposited in *D*, as shown. After a time the vent will become choked and perhaps entirely closed. If the vent pipe be attached as shown at *A*, the current of water will tend to create a suction and a downward current in the vent pipe, which will prevent the deposit of any grease or refuse at that point.

The vent pipe should be attached to the stack at such a height that, in case the waste pipe becomes choked, the waste water can not pass through the vent pipe into the stack without filling the fixture and thus giving notice to the householder that something is wrong. It also prevents an overflow by the discharge of waste water from the floors above. This is illustrated in Fig. 325.

956. The kitchen sink *A* is connected to the waste and vent-pipe stacks *B* and *C*. The waste stack is choked at

the point *D*, and waste water from the sinks above rise in the waste branch *E*, half fill the sink *A*, then discharge into the vent pipe *C*; thence into the drain, to which it is connected at its base. The cause of the chokage at *D* is presumably oakum, driven into the pipe by a careless workman, which accumulates falling solid bodies until the pipe is entirely closed. Tea leaves and coffee refuse make the chokage water-tight. It is common practice among plumbers to run the back-vent pipe in all cases higher than the fixture which it ventilates. This practice is not objectionable in small buildings or in private-residence work, but is decidedly objectionable

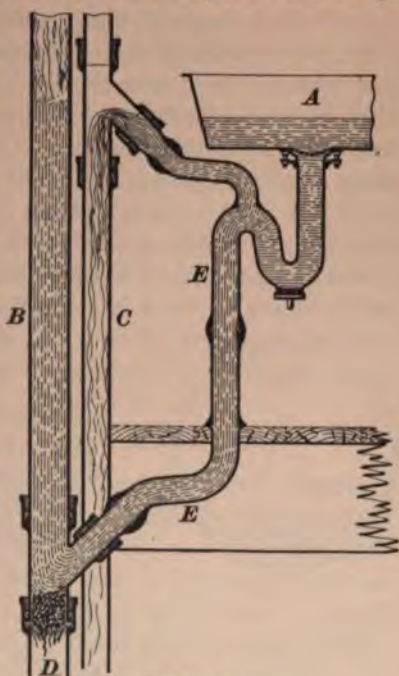


FIG. 325.

in tenement and apartment-house plumbing, particularly if the buildings are tall.

If the back-vent branches be too low, the dangerous state of affairs already explained may go on unnoticed, until finally the system becomes so clogged that the sewage will at last show itself somewhere.

957. A local vent is a device for creating an outward current of air, for the purpose of carrying away the offensive odors which arise in the bowl of a water-closet, urinal, or other fixture. It is attached between the fixture and the trap, or to the fixture itself.

Local vents should never be connected to the main ventilating stack or to any trap or soil-pipe vent, because if

they are so connected the gases from the soil pipe will be driven back into the house during stormy or windy weather. To secure a current of air that will be effective, the local vent pipe should be carried upwards, inside of a chimney flue which is in constant use, or the pipe may be run outside, but close against the flue, so that the heat of the chimney will help to create a draft. The outlet of the pipe should have a cowl to prevent the wind from blowing downwards in it. A local vent is useless without a good draft. The pipe should not be less than 2 inches in diameter for one closet or urinal, 3 inches for two or three closets or urinals, and 4 inches in diameter for 4 or 5 closets or urinals, if its length is not over 50 feet. It should be larger if the pipe is much longer or if it contains a number of bends.

DRAINS.

958. Drains should have a uniform **pitch** or fall throughout their length. The line of pipe must not have any part of it run on a level, nor should it be allowed to have any part of it sag below the general inclination, so that a pocket can be formed in which water will lie. The proper inclination or pitch to be given to drains varies with the diameter of the pipe, being greatest for the smallest diameter.

The inclination should be enough to give the water a velocity of about 275 feet per minute. A less velocity will fail to carry along the solids which usually accompany the water.

The proper fall for each size of pipe is given in the following table, 1 foot of fall being allowed for the length given under each diameter:

TABLE 38.

Diameter.....	2	3	4	5	6	7	8	9	10 inches.
Length to 1 ft. of fall..	20	30	40	50	60	70	80	90	100 feet.

Thus, a pipe 3 inches in diameter should be laid with a minimum fall of 1 foot in 30 feet of length.

The proper diameter of the pipe to be used for a drain is a matter which requires careful consideration. The pipe should be large enough to carry off, within reasonable time, the largest quantity of water that will ever be turned into the drain; yet, it must not be so large that the ordinary flow of water will fail to float and carry along the refuse that ordinarily accompanies the water.

Thus, the quantity of water which would run properly in a 5" pipe would, if passed through a 9" pipe, be so shallow that it would not float and carry the refuse along. This may be seen by observing the difference in depth between the water in the 5" pipe, shown in section in Fig. 326, and the same quantity in the 9" pipe, shown in section in Fig. 327. In Fig. 326



FIG. 326.



FIG. 327.

the solids discharged from the water-closets can easily be floated and carried along with the current without even touching the pipe. Since they do not touch the pipe and are submerged in the center of the moving water, it follows that they must move forwards as fast as the water which surrounds them.

In the 9" pipe, however, with the same quantity of water, the solids will touch the pipe, because the water is not deep enough to properly float them. The adhesion of the solids to the pipe will create such a resistance to their movement that the water will soon flow ahead and leave them behind, where they will remain until another flush comes and moves them forwards a little further.

959. The velocity with which water will flow through a pipe will depend upon the degree to which it fills the pipe. This is shown by the diagram, Fig. 328. If the level of the

flowing water is at D , and the length of the line $D E$ is taken to represent the velocity of the current, then the velocity of a quantity of water which fills the pipe only to the level F will be equal to the line $F G$. The difference is largely due to the relatively greater friction of the smaller stream, the proportion between the wet surface of the pipe

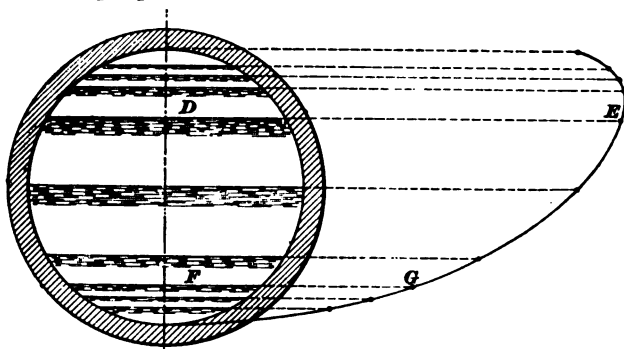


FIG. 328.

and the quantity of the water being much greater at the level F than at the level D .

It will be noticed that when the pipe is about three-quarters full the maximum velocity is attained.

A diameter of 4 inches is usually sufficient for a drain for an ordinary small dwelling; if the rain pipes empty into it, a 5 or 6-inch pipe should be used.

960. Care should be taken to lay drain pipes in a straight line. Every length of earthenware pipe should be cemented,

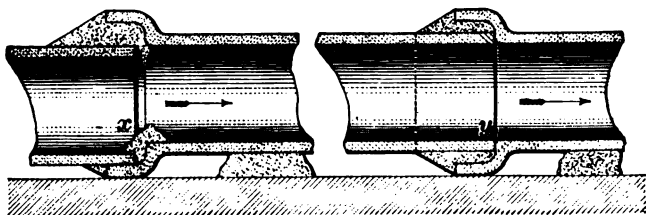


FIG. 329.

thoroughly cleaned, and examined inside before proceeding with the next piece.

When laying earthenware pipe care should be taken that no cement is left projecting inside the pipe as at *x*, Fig. 329. The inside surfaces of the pipe should lie flush and true as at *y*. All bends and curves should be of large radius. Right-angled branches and sharp turns should be avoided.

Drains should not pass under a dwelling if it can possibly be avoided. If the drain pipe passes through or under a foundation wall of a building, a liberal allowance must be made for the probable settlement of the wall. In new buildings and upon made ground the settlement is likely to be considerable.

Steam or very hot liquid should not be discharged into an ordinary drain. If there is much steam or hot liquid to be carried away, a special drain should be made for the purpose. It must never be discharged into a street sewer unless the liquid is first cooled off.

961. All drains should be provided with **inspection pieces** and **cleaning holes**, through which the interior of the pipe can be seen, and through which cleaning tools can

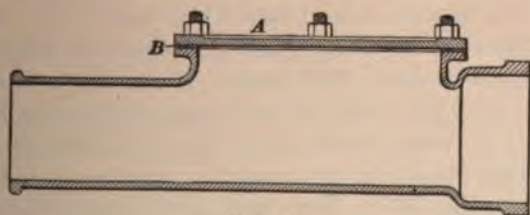


FIG. 330.

be introduced. Care should be taken in locating these pieces or handholes that sufficient room is provided around them to handle the cleaning tools.

Such an inspection piece is shown in Fig. 330. The cover *A* is secured by bolts, and is made air-tight by a rubber or other suitable gasket *B*. These fixtures should be located at each bend in a main drain, so that every part of the drain may be examined with a lamp and mirror when

desired. The inspection piece shown in Fig. 330 is particularly adapted for placing at regular intervals of 75 to 100 feet along a straight underground drain, where it would be built in a brick manhole about 3 feet long by 2 feet wide.

Two elbows with an inspection hole and covers are shown in Fig. 331. *A* is suitable for joining two horizontal drains, while *B* is suitable for a vertical and horizontal junction.

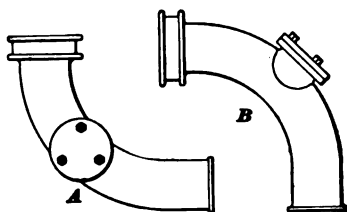


FIG. 331.

FLUSHING DRAINS.

962. Drains should be flushed periodically, to wash them clean and remove all accumulations of filth. To do this properly, a large volume of water is necessary, and it should be released suddenly. The flow should be sufficient in volume to completely fill the bore of the pipe, and the head should be great enough to insure a swift and forcible current.

963. Automatic flushing tanks for this purpose are constructed to receive and store the water from the roofs, and sometimes the water from the wash-bowls and bath-tubs is stored in a tank of this kind. When the tank becomes full, it discharges itself in a strong, steady stream, thus effectually scouring the drain to which it is attached.

The construction of an apparatus suitable for the purpose is shown in Fig. 332. The tank *A* is built of brick and is lined with Portland cement or asphaltum, to make it watertight. It is circular in form, the bottom is arched as shown, and a manhole with cover and air vent is provided at the top. The outlet is controlled by a siphon composed of outer and inner pipes *B* and *C*, which are fastened together by suitable brackets. The foot of the siphon rests in a tapered socket *D*. When the water rises to the level of the top of the tube *C* and begins to overflow, the air is quickly driven out of the tube, and the siphon thus starts itself, and the flow

continues until the water falls below the end of the outer tube *B*. The diameter of the pipe *C* should nearly equal the diameter of the drain pipe, which is to be flushed, so that the water will pass through in a nearly solid column until the tank is emptied.

The tank in Fig. 332 is shown built in the ground at the

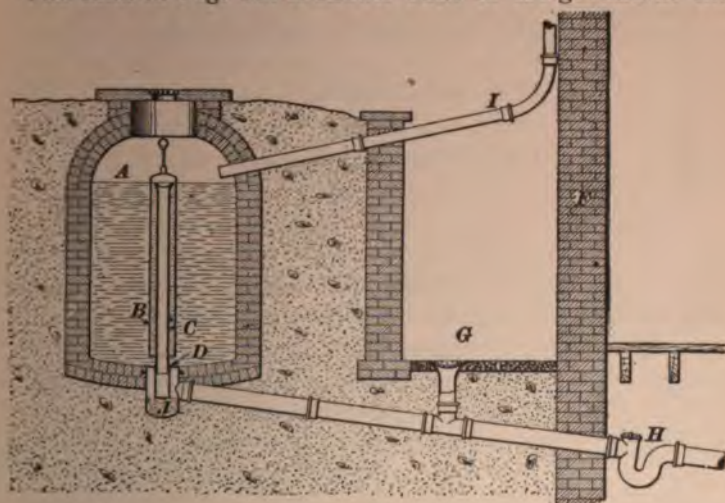


FIG. 332.

rear of a building, of which *F* is the back wall and *G* the back area. The trap *H*, which forms the top end of the house drain and receives area water through the surface grating shown, also receives the discharge from the tank and at the same time disconnects it from sewer gases. The tank is filled by roof water through the conductor *I*.

The head of the **inner siphon tube** *C* should be constructed as shown in Fig. 333. The object of this peculiar construction is that the water which flows over the rim of the funnel shall be concentrated at the center of the pipe, thus expelling the air from the pipe more effectively than it could do if it ran down upon the inside surface of the pipe.

The seal of the trap *J* should be about $\frac{1}{8}$ of an inch or less, as its only use is to hold back the air which is driven

through by the siphon while starting. To prevent the siphon from running constantly, and passing a volume of water equal to that flowing in—in other words, to completely break the siphonic action at the end of a flush—a small pipe siphon is sometimes attached to drain the water-line of the trap below the bottom of the inner tube *C*, so that air may gain free admission into the siphon. This small siphon is started by the flushing of the larger one.

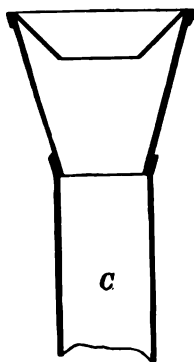


FIG. 333.

The siphon may be started by hand at any time, by raising it from its seat in *D* and thus starting the flow through the trap *J*. The current thus generated is sufficient to start siphonage as soon as the siphon is dropped back into its socket. There are many other forms of flushing tank apparatus on the market, and many of them are more positive than the form shown.

PLUMBING AND DRAINAGE.

(CONTINUED.)

LEAD BURNING.

APPARATUS.

964. The process called **burning** is used for joining the edges of lead sheets or pipes without solder. The edges are fused to an extent which permits the parts to unite and form one solid piece when cooled. This process is known as the **autogenous process**, and although it has been practised for centuries, it is used far less at the present day than it should be. It affords a quick and cheap method of making lead joints of the most durable character, and it may be used with profit in many cases instead of the soldering process now commonly employed.

Solder can not be used for joints which are exposed to contact with acids, because most of the ordinary acids will dissolve the tin, of which the solder is in part composed.

Tanks which are used for the manufacture or storage of acids or acid salts, or for the storage of mineral oils, petroleum, etc., are usually lined with lead. The joints in these linings, and in all of the lead pipes which are used for the same purpose, must be made by burning.

The operation is performed by melting the edges to be joined, a drop at a time, by means of a blowpipe. It is essential that the flame which is used shall not oxidize or tarnish the metal. If the drop of melted metal does oxidize, it will not unite with the solid parts, and the joint will be a failure.

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The most certain and convenient way to secure a non-oxidizing flame is to use hydrogen gas mixed with air to supply the blowpipe. Other methods may be employed, but none are so convenient as the hydrogen gas process.

965. The apparatus required for lead burning consists of a gas generator, an air pump, and storage tank, or

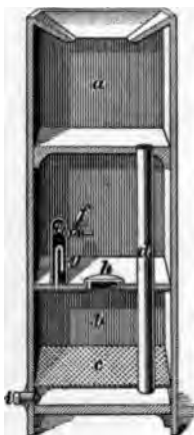


FIG. 334.

"holder," and a compound blowpipe. The internal construction of a generator and gas holder is shown in Fig. 334. The **gas generator** consists of an open chamber *a*, which is lined with lead, and a lower chamber *b*, also lined with lead, and which is made air or gas-tight. A perforated pan, or tray, *c* is suspended an inch or more above the bottom. The upper and lower chambers are connected by a lead pipe *d*, which extends below the pan *c*, as shown. The chambers are protected by a stout wooden casing against injury or accidents; the casing also serves to retain the heat which is generated in *b* while making gas. The gas passes upwards through the bent pipe, which dips about $\frac{1}{2}$ inch below the water that is contained in the chamber *e*. Thus the gas is compelled to bubble upwards through the water before it passes out of the cock *f* to the blowpipe. This arrangement constitutes a *fire trap* which will prevent an explosion in the hose from firing the gas in the machine. In order to regulate the height of the water in *e*, a small pet-cock, or plug, *g* is provided.

966. To make gas, a quantity of commercial zinc, in lumps from 1 to 2 inches long, is placed in the copper pan *c*. The plug *h* is then screwed into place and made gas-tight, and the gas cock *f* is opened. Having previously ascertained, by experiment, the quantity of water which will exactly fill the chamber *b*, a mixture of five parts of water and one part, by volume, of commercial sulphuric acid is prepared. A quantity of this mixture, which will just fill the

chamber *b*, is then poured into the upper chamber *a* and allowed to flow into *b*. The generation of gas will begin as soon as the acid mixture encounters the lumps of zinc in the pan *c*, but as the cock *f* is open the liquid will all flow into and entirely fill *b*, thus forcing the air in *b* to the atmosphere.

When *b* has been entirely filled, that is, when all the liquid poured into *a* has flowed into *b*, and gas and liquid spurt out of the cock *f*, the cock is closed, and the rubber tubing which is to conduct the gas to the blowpipe is then attached to *f*. The gas generated in *b* will now rise to the surface, and by accumulating there will force the liquid up the tube *d* and into *a*. The pressure of the gas will increase with the height of the liquid column in *d* and *a*. As soon as the liquid in *b* is forced below the perforated pan the formation of gas will cease, and, of course, at this point the maximum pressure of the gas will be obtained. The machine will then be ready for use.

The object of blowing the air out of *b* before allowing gas to accumulate is to prevent a mixture of air and gas, which is explosive, and which, if ignited, may blow the machine to pieces and injure or probably kill the workman.

The machine should not be allowed to stand over night with a charge of liquid in it, because it will clog up with a deposit of sulphate of zinc. As soon as the workman is finished for the day, the drain plug *i* should be removed and the apparatus emptied of liquid. Two pails of clean water should be run through it to remove the deposits and cleanse it.

The utmost care must be taken to keep the chamber *b* perfectly air-tight. Its tightness should be frequently tested by shutting the cock *f* and filling the upper chamber with clean water, allowing it to stand for at least one hour and taking note of the exact height of the water. If the water sinks during the test, a leak is surely indicated; and if a leak exists, the machine must be examined until the leak is found and repaired. A very slight leak may cause a disastrous explosion.

967. The zinc which is used for making gas should be of the ordinary commercial quality. Pure zinc works very slowly, and is not satisfactory. About 3 ounces of zinc will furnish one cubic foot of gas. The charge of zinc should be about 20 to 25 pounds for a machine that is intended to run all day.

A generator of convenient size would be about 10 inches square, and 33 to 36 inches high. A larger machine would be advisable for heavy work. If the amount of liquid contained in a generator is small in proportion to the amount of zinc, it will soon become saturated with the sulphate of zinc which is formed during the process of making gas, and the evolution of the gas will cease. Considerable heat is liberated while the gas is forming, and the generator works best while hot. As soon as the temperature falls, the sulphate will begin to crystallize and will form a coating all over the pieces of zinc; it may clog up the holes in the pan *c*, or it may even choke up the inner end of the delivery pipe *d*.

This clogging may occur while the workman is away at dinner. If the liquid is not nearly saturated with sulphate, or "spent," it should be driven back into the upper chamber by attaching the air pump to *f* and pumping air into *b*; by inserting a wooden plug in the top of *d* the liquid can be held in *a* as long as desired. Then the zinc can be taken out and washed clean with hot water. Care must be taken to force the air out of the machine, as previously directed, before resuming work.

Explosions of hydrogen gas mixed with air are very violent, and care must be taken at all times to keep away all lights or fires from the vicinity of the generator while opening it, or while blowing out any gas. This danger is probably the chief drawback to the use of the machine, but in the hands of careful workmen no trouble is likely to happen.

968. The air supply necessary to operate the blowpipe may be furnished by a bellows or a blower, or almost any

kind of a pump, but to operate the blowpipe to the best advantage, the air blast should be perfectly steady and smooth. A good way to obtain a proper blast is to use the **air holder** shown in Fig. 335. This consists of a hollow cylinder *a* of galvanized iron, open at the lower end, which is immersed in a tank of water. The outer tank *b* should be about one inch larger in diameter than *a*. The cylinder *a* should be confined by suitable guides, so that it can not tip sideways and bind. The air cocks may be attached to the top of *a*. The pressure of the blast may be regulated by placing more or less weight upon the top of the floating cylinder. One of the air cocks should be connected by rubber tubing to the blowpipe, and the other to the air pump *C*, Fig. 336. In practice the pump is operated until *a* rises to its highest limit, and the cock is then shut off until *a* has sunk nearly to the bottom of its range, when pumping is repeated. Continuous pumping is not required. Care must be taken that the pressure of the air is not greater than that of the gas from the generator. Otherwise the air may work back through the gas tube into the generator and cause an explosion of the apparatus.

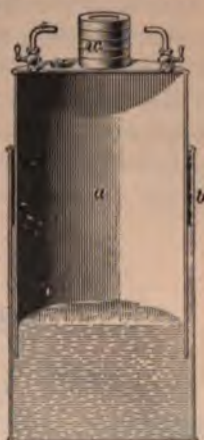


FIG. 335.

969. Fig. 336 shows the general arrangement of the apparatus. The gas from the generator and the air from the holder are not mixed until they reach the mixing pipe *a*. The proportions of air and gas are determined by adjusting the cocks to which the rubber tubes are attached, and the force of the jet is also adjusted in the same way. This mixing pipe should be as closely behind the blowpipe as convenience will permit. The mixture of air and gas is very explosive, and the fire may flash back from the jet to the mixing pipe, spoiling the tubing, if nothing worse. In some forms of blowpipe the mixing cocks are

attached to the blowpipe. The blowpipe should be provided with several sizes of jets, or nozzles. A jet of $\frac{1}{8}$ of an inch bore is of proper size for working on 4-pound lead. The diameter of the bore of the nozzles used for heavier lead will increase slightly with the thickness of the sheet. About $\frac{3}{8}$ -inch bore will be required for 12 to 20-pound lead.

The rubber tubing which connects the blowpipe to the gas generator and the air holder should be of $\frac{1}{4}$ -inch to $\frac{3}{8}$ -inch bore, and of extra heavy rubber, so that it will not kink. It should be connected by means of screw couplings. If the

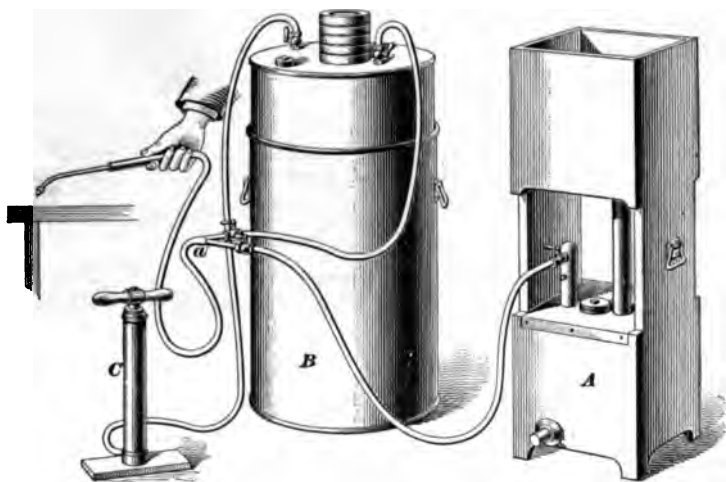


FIG. 336.

tubes are merely slipped over nipples, and are not wired, they are liable to be pulled off while working.

Vapor is liable to condense in the tubes; clots of water are liable to be blown into the blowpipe and extinguish the flame. In that event, the tubes should be disconnected and hung up to drain until they are dry. The tubes should be detached from the generator and the air holder at the end of each day's work, and be hung up to drain and dry out.

The cock on the generator should be kept closed while the blowpipe is not in use, but should be opened wide when ready to proceed with work. The regulation of the gas flow should be done by the gas cock on the mixing pipe.

970. To start the blowpipe, the air cock is first shut; then the gas cock is partly opened, and as soon as gas flows from the jet, it is ignited. The flame at first will be long, noisy, and unsteady, with very little color. The gas cock is then gradually closed until the flame is reduced to about 3 inches in length. The air cock is then slightly opened, and air is admitted to the flame. The supply of air is gradually increased until the flame is shortened to about $1\frac{1}{2}$ inches, or until the flame is sharp pointed, compact, rapidly darting,



FIG. 337.

noiseless, and divided into two well-defined flames, one inside of the other. The inner flame should be very distinct, and its apex, which is the point of greatest heat, should be blue. The outer flame is of a pale reddish color, and its temperature is much lower than that of the inner flame. The two flames differ greatly in their effect upon metals. The outer flame will oxidize the metal that it touches, but the inner flame will melt the metal and keep it hot as long as desired without oxidizing it. Consequently, the inner flame is used

exclusively in the operation of lead burning, and the contact of the outer flame with the metal is avoided as much as possible.

971. Fig. 337 exhibits the various forms of the flame as the proportions of air and gas are changed. The clear gas makes a flame like *A*. As air is introduced in increasing quantities the flame takes the successive shapes *B* to *F*. The correct working shape is shown by *F*. Too much air is shown at *G*, and *H* is on the point of *going out* from excess of air or lack of gas.

It should always be borne in mind that the gas must be turned on and ignited before air is admitted, and when it is desired to extinguish the flame, the air must be shut off before the gas cock is touched. To increase the flame, increase the gas first, then increase the air. To diminish the flame, check the air first, then reduce the supply of gas.

MANIPULATION.

972. To learn the characteristics of the flame, and how to handle it, the student should practise on a piece of sheet lead which has been cleaned with the shave hook. Bring the point of the inner flame quickly down upon the clean lead. Almost instantly a disk of melted lead will be formed; then quickly remove the flame. The melted metal will cool bright, showing that it has not been oxidized. Now, bring the end of the outer flame to bear on the clean lead, keeping the inner flame about $\frac{1}{8}$ or $\frac{1}{4}$ of an inch away. The lead will quickly tarnish, and, although it will melt, it will be covered with a coat of gray oxide.

Again bring the point of the inner flame to bear on the clean lead, melt a little, and then withdraw the flame slowly, allowing the outer flame to act on the molten part; a film of gray oxide will spread over the molten metal, and it is then spoiled for joining purposes.

It will also be found that unless the flame is withdrawn with proper quickness, ugly holes will be made in the sheet metal.

Further experiment will disclose the fact that if a **bead**, or drop of lead, is maintained in a state of fusion, and if a small part of the leaden sheet upon or against which the lead rests is also fused, the lead will quickly flow to and unite with the molten part of the sheet, and will, upon cooling, form a perfectly homogeneous mass with it. The union will be perfect, provided that all oxidation is avoided. This is the essential part of the process of *lead burning*. The attraction of the two portions of melted lead for each other is so strong that the effect of gravitation upon the bead is apparently diminished to a considerable extent, and it is found that the bead can be made to travel in almost any direction.

The size of the bead must be varied to suit the thickness of the metal which is to be joined, and also to suit the direction of the joint, whether horizontal or vertical, inclined or inverted.

The strength of a joint made by burning depends a good deal upon the size of the bead made by the blowpipe flame; therefore, it is important that the bead should not be made too small. If the bead is too large, the joint will present a very uneven surface, as the weight of the bead will overcome the attraction of the melted metal near it, so that it will fall away from the desired place, and be unmanageable.

Care must be taken to avoid fusing too large a spot in the sheet at any one time, because the sheet will be thinned out and weakened by it.

Fig. 338 shows two sections of lapped joints, one of which *A* is properly made, and the other *B* has been badly weakened by too much fusion, as above referred to.

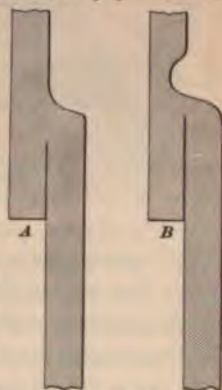


FIG. 338.

973. The student is advised to begin practice upon a **butt seam** on the bench. He should first prepare two

pieces of sheet lead, by planing the edges to be joined straight and square, and shaving the top surfaces clean about $\frac{1}{4}$ inch wide upon each side of the butt joint; then butt the edges together and secure the sheets firmly to a board. The extra lead which is necessary to make a butt joint, that is, to supply the beads, must be obtained from a **lead stick**. This should be $\frac{1}{8}$ inch or more thick, triangular in section, and shaved clean.

The blowpipe flame being regulated to the proper shape and size, the burning is begun at the nearest end of the joint, as shown at *a* in Fig. 339. With the point of the inner flame

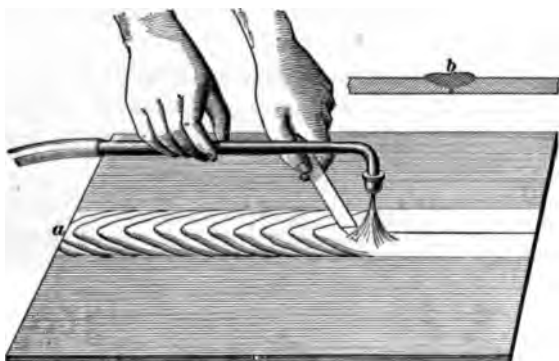


FIG. 339.

melt off a drop of lead from the end of the lead stick and allow it to fall squarely on the seam. Follow it up instantly with the flame, placing the point of the inner flame exactly over the edges of the seam, which are under the bead. They will quickly melt and unite with the bead. The flame must be withdrawn before the fusion proceeds any further than necessary to secure that one bead in place. If the operation is properly performed, a section through the bead would appear as at *b* in Fig. 339. Now proceed to drop another bead upon the seam, but lapping about $\frac{1}{3}$ of its diameter on the previous bead, and secure it to the seam in the same way. Each successive bead fuses into and unites with the preceding one and with the edges of the sheets, thus forming a continuous joint. The student will soon

learn to make the beads follow each other in rapid succession. The movements of the blowpipe in melting off the bead, dropping it on to the seam, fusing the edges of the seam, and backing off from it, are repeated in quick succession, the hand of the operator moving in a circular path, and gradually advancing from him as the joint progresses.

Making this form of joint should be practised until perfect control of the flame is secured, and the operator learns how to handle the blowpipe so as to secure the beads in their proper place uniformly and rapidly.

974. The next thing to be learned is how to make a **flat lapped joint**, as shown in Fig. 340. The sheets

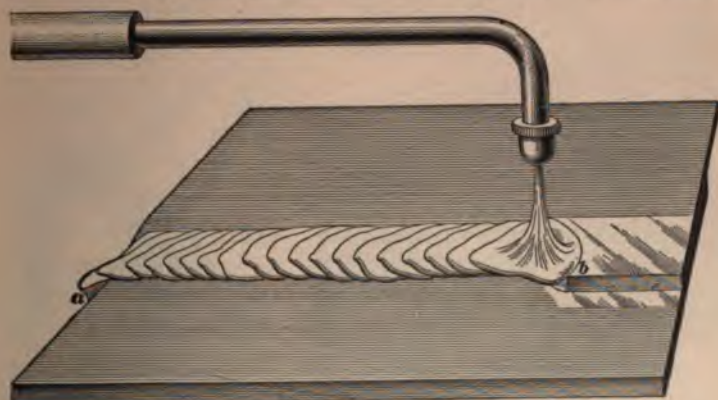


FIG. 340.

should be planed, squared, and shaved where they touch each other, and the upper surfaces should be shaved clean about $\frac{1}{4}$ of an inch each side of the edge of the upper sheet as shown. They should lap about $\frac{1}{2}$ inch for 6-pound lead.

In lapped joints no lead stick is required, the beads being melted off the edges of the upper sheet. Beginning at *a*, the flame is first brought to bear upon the upper edge *b* of the top sheet, and a bead is melted off. The flame is then quickly moved backwards and downwards so that it will bear on the lower sheet. The bead will follow the flame,

and as soon as the lower sheet begins to fuse, the bead will promptly unite with it. The flame must be instantly lifted away and returned to the edge of the sheet for the next bead. Each successive bead is similarly secured a little in advance of, but lapping on, the preceding one. In performing the successive movements required to fix each bead, the hand of the operator travels continually in small circles, and slowly advances as the joint progresses.

A skilful operator will fix each bead firmly and evenly in place, and never deviate from the proper line of the seam.

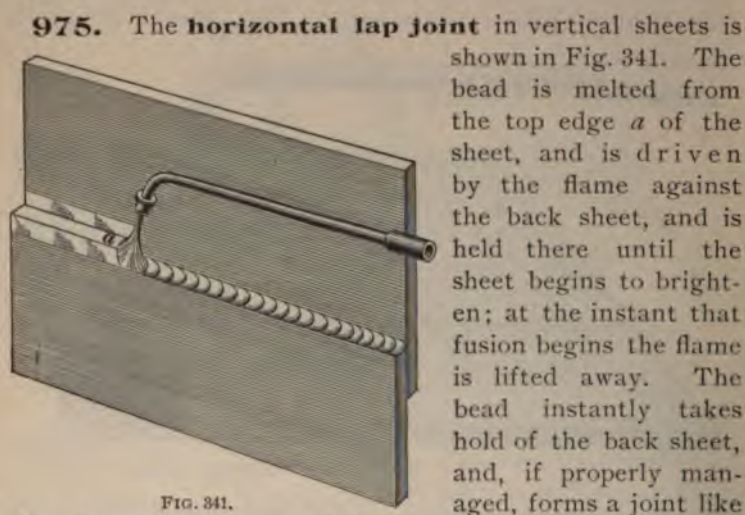


FIG. 341.

that shown in section at *A* in Fig. 338.

976. The **vertical lap joint** is shown in Fig. 342. The joint is begun at the bottom of the seam and is gradually worked upwards. The bead of lead is melted off at *a*, and is flowed downwards to *b*, where it is united to the back sheet as in previous operations. However, the bead does not flatten out so much as in horizontal seams, but cools in the form of a split pea.

In making vertical and inclined joints, the size of the bead becomes a matter of great importance. The student is

advised to make vertical seams for practice, noting the size of the bead employed; and then cut squarely across the joints so made, and ascertain the extent and apparent strength of the joints. No reliable knowledge upon that point can be obtained in any other way.

The knowledge gained by experimenting with vertical joints will enable the student to make inverted joints, that is, joints having the lap on the under side. These joints can not always be avoided,

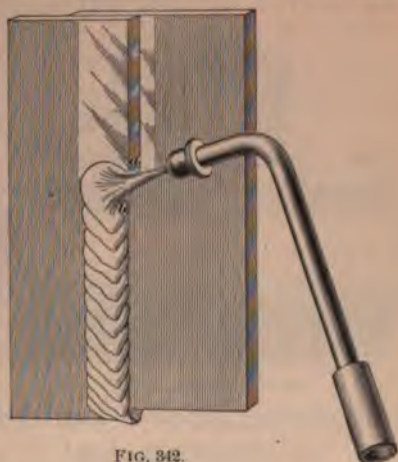


FIG. 342.

and while they require a little more patience and skill than the ordinary horizontal joints, the art of making them can be readily acquired.



FIG. 343.

to fit snugly within the socket, and is scraped clean about $\frac{1}{8}$ inch above the edge of the socket. The blowpipe is then applied as for making a horizontal seam in a vertical sheet. (See Fig. 341.)

977. The mode of burning joints in vertical pipes is shown in Fig. 343. The end of the lower section is first cupped as for an ordinary solder joint, and is then dressed into a socket, as shown, and is shaved on the inside, on the top edge and down over the outside about $\frac{1}{4}$ inch. The upper section is rasped to fit snugly within the socket, and is scraped clean about $\frac{1}{8}$ inch above the edge of the socket. The blowpipe is then applied as for making a horizontal seam in a vertical sheet. (See Fig. 341.)

978. Fig. 344 shows the mode of burning a T joint. Care must be taken to preserve a proper thickness of metal

at *a*, when opening out the hole to fit the branch. If the metal is thinned out, there is great liability of burning

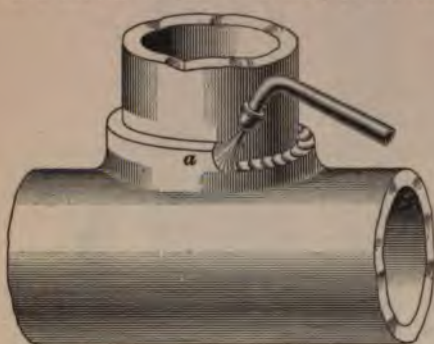


FIG. 344.

a hole through at that point, or in being compelled to feed the flame with a lead stick. In making joints in horizontal pipe, the angle of the seam varies from the horizontal at the top to the vertical at the sides, and to the inverted position at the under side. The joint should be begun at the bottom and be worked both ways towards the top.

LINING TANKS.

979. The sheet-lead lining should be cut so as to require the least possible number and extent of joints. As many of

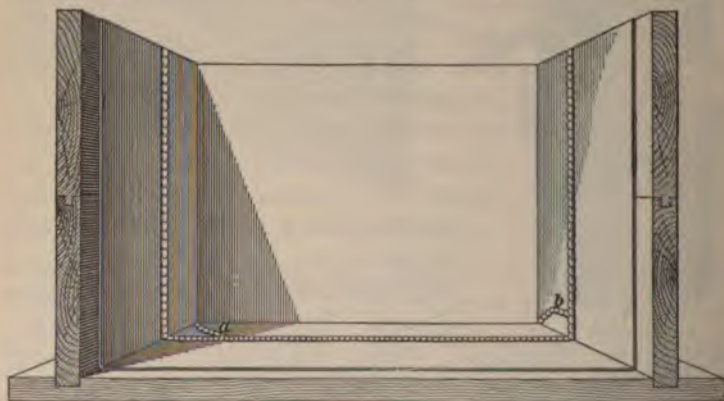


FIG. 345.

the joints as may be practicable should be made in the bottom, because of the less amount of labor that is required to make them.

Fig. 345 shows the arrangement of the joints for a tank, say $6\frac{1}{2}$ ft. $\times$ 4 ft. $\times$ $2\frac{1}{2}$ ft. deep. The bottom and two sides are made of one piece, which extends to within about 3 inches of each end. Each end section is formed with a 4-inch flange around the bottom edge and each side, thus lapping one inch over the bottom and side sheet.

The corners formed by the flanges may be closed with a miter joint, lapped as at *a*, or a horizontal seam, as at *b*.

The top edges of all the vertical sheets should be lapped over the edge of the wooden tank sides and be secured with copper nails in the usual manner.

When the sides of the tank are large the sheet-lead lining must be supported at intervals by means of buttons, that is, brass screws having their heads protected by burning over them.

980. The lead sheets are prepared for the tank, as shown in Fig. 346. Having ascertained the exact width of the tank in the bottom, and making sure whether the width is the same at both ends and in the middle, the sheet is scribed off accordingly. The helper should stand on the straight edge *a* and hold the edge of the part *b* while the workman dresses the bent edge into a square corner, working the dresser *c* against the straight edge. Allowance must be made for the thickness of the metal when scribing the sheet, before bending. When the corner is properly squared the sheet should be rolled together, beginning at the top edge, making a bundle, as at *d*; the other side is rolled down in the reverse direction, making a double bundle. When the entire piece is thus rolled it can

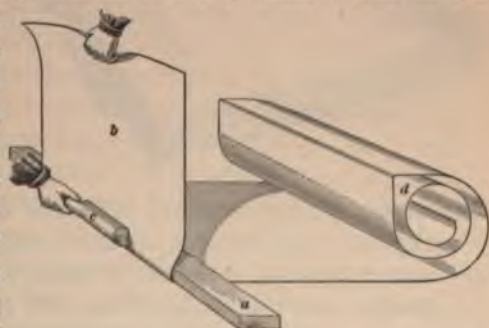


FIG. 346.

be handled readily, and should then be put into its place in the tank.

When it is unrolled the bent corners should fit the angles between the sides and bottom, so that the lead will not be stretched when set home. After setting the lead well into the angles, it should all be flapped to a smooth surface with a sheet-lead flap, and be nailed over to the edge of the tank. The ends of the tank are then carefully measured and it is found whether the width of the tank is the same at the top and bottom, whether the angles are right angles, and whether the sides are square with the bottom at both ends. If this measuring and testing are neglected, some very annoying misfits are likely to occur.

981. The flanges are then formed up, as shown in Fig. 347, and the corners lapped and scraped to make proper corner joints. The flanges are scraped

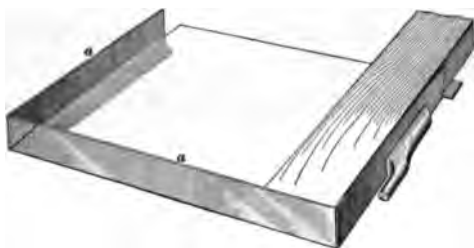


FIG. 347.

clean on the edges *a*, and $\frac{1}{2}$ inch down on the outside all the way around, and similarly about $\frac{1}{4}$ inch down on the inside. The end

sheets are then lowered into place and set home snugly into the angles. The flanges should overlap the bottom and side sheet $\frac{1}{2}$ inch or more at each end. The edges of the flanges are then scribed on the under sheet, and the flanges are raised to facilitate scraping the border of the under sheets so that the joint may be properly burned. The flanges are now dressed down again, and the process of burning the seams begins. The flat bottom seams should be burned first, then the vertical seams, commencing from the ends of the horizontal seam and working upwards, as before described. Great care must be taken when burning the corner seams *a* and *b*, Fig. 345, that the burning is continued fully into the corner, so that no small pin-hole can remain.

DRAINAGE.

TESTING DRAINS, ETC.

982. Earthen drains should be carefully tested for leakage before the trenches are filled. The low end of the line of pipe should be plugged, and all branches should be stopped temporarily. The drain should then be filled with water, and allowed to stand full for a few hours. If the water settles down in the pipe, the leak should be found and stopped. A pressure of at least 1 pound per square inch should be put upon every joint and pipe in the system, or they may be tested by smoke.

983. All the drain, soil, waste, and vent pipes within a building should be thoroughly tested by water pressure, or the **hydrostatic test**, as it is called, before they are enclosed, and before the fixtures are attached. The pipes should be tightly plugged at or near the main trap where they pass out of the building, and the end of every branch should be stopped water-tight. The system may then be filled with water by pouring it into the top of the stack with pails; or water may be forced in from below with a pump, or a temporary connection may be made with the street main. The pipes should be allowed to stand full for several hours, unless they are subject to frost, when they should be emptied before the water freezes. If the water sinks, then every pipe and joint should be inspected until the leak is found and remedied. A little more calking will usually suffice to stop a leaking joint in cast-iron pipes. However, if a cracked or split pipe or hub is found, the pipe should be removed and a sound piece should be put in its place. Patching or repairing should not be attempted; honest and durable work can be done only by replacing the damaged parts with new and sound pipes.

After the short waste branches are all attached and the fixtures are connected, the entire system of drain, waste, and vent pipes must be tested and made gas-tight.

984. The test by water pressure is applied only to the iron stacks, branches, and drain pipes; but it is just as important that the fixture connections be made gas-tight, so a test should also be applied to them when the fixtures are all connected up and the traps sealed. The pressure of such a test must be less than that required to force the trap seals. To find whether the system is gas-tight, an **air test** may be applied by means of a pump. All the traps are filled with water, and every opening is carefully stopped. The air pump is then connected, and a pressure about equal to that required to sustain a column of water $1\frac{1}{2}$ inches high is applied to the whole system. A water gauge which will show the height of a water column required to resist the air pressure should be attached at some convenient point, by which the pressure may be noted.

If any of the traps *blow through*, or bubble, at a lower pressure than $1\frac{1}{2}$ inches, they should be readjusted until they will hold that pressure. If that can not be done, the trap should be condemned and a better one should be put in its place. If there are no running traps on the system (a bath trap, for instance), a pressure of 3 inches water column may safely be applied.

After the pressure is put upon the system, the pump should be shut off, and the water gauge should be closely watched for several hours. If the pipes are all tight, the gauge will show no loss of pressure; but if the pressure falls, then a leak is surely indicated. To find the leak, resort must be made to other tests. Two methods are commonly employed for this purpose: one is to fill the pipes with a dense smoke, which can be seen when it escapes from the leak; this is known as the **smoke test**; the other is to fill the pipes with some strong pungent odor, which can easily be detected by smell—such, for instance, as the oil of peppermint. Care should be taken to distinguish between the *oil*, which is the essential oil, and the *essence*, which is a solution of a small portion of the essential oil in a large volume of alcohol, and is useless for this purpose.

985. To apply the smoke test, a smoke machine is required. This consists of a blower which forces air into an air-tight fire-box in which a fire is maintained. Usually a bunch of cotton waste, which has been saturated with machine oil, will furnish all the smoke required when slowly burned inside the fire-box. The smoke is conducted through a flexible hose composed of asbestos or rubber, or through metal pipes, to the fresh-air inlet of the drainage system, or to the most convenient branch, or open end. The ends of the branches and vent pipes should then be opened to allow the smoke to displace the air and penetrate to every part of the piping. All doors and windows should be closed, and the smoke made in starting the apparatus should be carefully prevented from entering the building. If it does get into the building, it will affect the air so that it will be difficult to detect the smoke which will ooze out through the leaks in the pipes. As soon as the smoke has penetrated throughout the whole system and shows itself at all the openings, the plugs should be replaced and the openings made air-tight. The pressure is then put on again as before. Sooner or later the smoke will ooze through the leak and become visible, and have a perceptible smell also. It will also make its way through the traps if they are insufficiently sealed.

986. The **peppermint test** may be applied in the same way by putting some of the oil of peppermint into the apparatus instead of the smoking material. A more convenient way is to pour from 3 to 5 ounces of the peppermint into the top of the vent stack, and follow it up with a half gallon or so of boiling water. The hot water makes the peppermint more volatile and helps to diffuse the odor throughout the pipe system. All the outlets should be closed and the air pressure should be put on as before.

The odor will penetrate through the smallest leak if the vapors are under pressure, but in order to determine the location of the leak it is necessary to carefully smell the pipe system from beginning to end. Great care must be taken

in handling the bottle of peppermint that none is spilled or is smeared on the hands or clothes of the operator, because then he will not be able to tell whether the smell proceeds from the leak or from himself.

987. A convenient form of smoke machine is shown in Fig. 348. It is composed of a double-action bellows underneath and a fire-pot *b* above. The inlet valves to the bellows are in the middle leaf, as shown, and an outlet valve is in each end leaf. When the handle *c* is operated, the bellows blow air through a three-way cock *a* into the bottom of the fire-box. The fuel rests upon the grate *e*, and when ignited on the bottom the smoke blows through *b* in the direction of the arrows and passes through the outlet tube *g*, which is to be connected to the drainage system by a $1\frac{1}{4}$ or $1\frac{1}{2}$ -inch hose pipe. A water-jacket is formed around the fire-box, and this must be nearly filled with water before the fire is started. A drum or cover *f* encloses the fire-pot and is sealed in the water. The weight of the drum is such that a pressure of about 1 inch water column will raise it, or cause it to float in the water. A greater pressure is not required, and can not be formed unless the drum is loaded down with weights. If the bellows are operated when the drum is floating, the result will

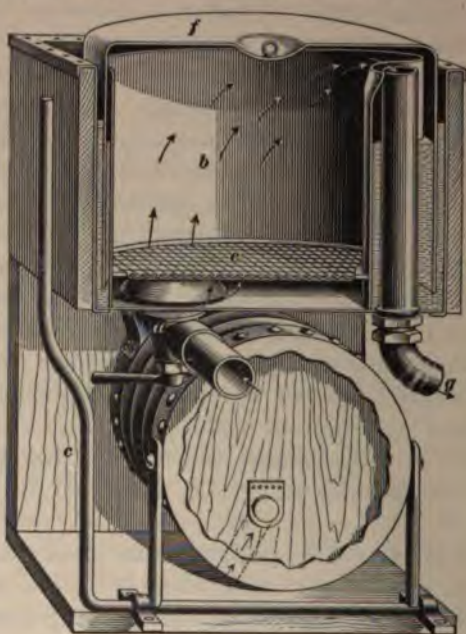


FIG. 348.

be connected to the drainage system by a $1\frac{1}{4}$ or $1\frac{1}{2}$ -inch hose pipe. A water-jacket is formed around the fire-box, and this must be nearly filled with water before the fire is started. A drum or cover *f* encloses the fire-pot and is sealed in the water. The weight of the drum is such that a pressure of about 1 inch water column will raise it, or cause it to float in the water. A greater pressure is not required, and can not be formed unless the drum is loaded down with weights. If the bellows are operated when the drum is floating, the result will

be that the surplus smoke will escape to the atmosphere from below the drum. This prevents the trap seals from being forced by accident.

When the drainage system is full of smoke and the drum floats, the cock *a* is closed and pumping is stopped.

If there is a leak anywhere, the drum *f* will sink in the water, and the velocity with which it falls will indicate the extent of the leak.

If the drainage system is gas-tight, however, the drum will continue to float in the water. The length of time which the drum should float, when the test is applied to a small job, is from 5 to 10 minutes; and if it does not show any appreciable fall in that time, the work should be passed as tight. Larger jobs require a correspondingly longer time of test, because of the larger volumes of smoke in the systems.

The smoke test is recommended as a final test in preference to peppermint or air. It is coming rapidly into popular favor. Many health departments compel it, and it is used by leading sanitary engineers and plumbers.

988. The **plugs** used for closing the open ends of pipes for low-pressure tests, such as the smoke, the oil of peppermint, or even the water test in low buildings, are usually made tight by compressing a soft rubber ring against the inside of the pipe by means of two disks beveled on their outer edges to fit the rubber ring.

When the disks are spread apart the rubber contracts, and when they are pushed together, usually by a thumb nut, the ring is expanded and its diameter increased. Plugs which depend only upon the friction between a soft rubber ring and the internal surface of the pipe for resistance to water pressure are liable to be blown out, particularly if the diameter of the pipe is greater than 4 inches. In testing the pipes in high buildings it is advisable to close the open ends subject to great pressure by calking cast-iron plugs, similar in make to ordinary threaded plugs for wrought-iron pipes, only with coarser threads, so that they will have greater resistance to the pressure. When the test is over they can easily be unscrewed and the lead and oakum picked out.

FREEZING OF PIPES.

989. All water pipes in exposed places should be well protected against frost. They should be wrapped with some material that will conduct heat very slowly. Hair felt is very often used, but unless the felt be covered so as to be air-tight (or nearly so) with canvas or other material, currents of air will blow through the felt and cool the pipe. The covering over the felt encircles a space which is partly taken up by the felt and partly by air.

Cold drafts in pipe chases should be avoided by having the tops and bottoms of the chases closed. Water pipes should not, in very cold climates, be fastened to outer exposed walls of buildings unless the walls are hollow—that is, having air-tight spaces between the outer and inner sections of the wall. They should rather, if possible, be attached to inside walls and partitions.

The cause of pipes bursting by frost is due to a peculiar property of water. When water is reduced in temperature to 39.2° F., it attains its **maximum density**; that is, water at this temperature occupies its smallest possible volume. If water at this temperature be heated, it will expand; if cooled, it will also expand.

Water, then, expands while being decreased in temperature from 39.2° to 32° F., or freezing point. If water did not thus expand and become lighter, but continued increasing in density (becoming heavier) with the decrease of temperature, it would solidify at the bottom first. When water changes from the liquid to the solid state it rapidly expands about $\frac{1}{9}$ of its volume. This increasing in volume while freezing is the cause of water pipes bursting when they freeze.

990. A pipe full of water may be frozen and not burst, while another, containing less than a pint, may burst. For example, in Fig. 349 we have a $\frac{3}{4}$ -inch pipe laid perfectly level, so that there shall be no circulating currents in its length.

A current of cold air blows against the pipe. The center

of the current is supposed to be the coldest part, the current being slightly warmer towards the points *A* and *B*, but still cold enough to freeze the water at these points. The point *C*, or center of the pipe, will freeze first, and the water will gradually solidify from this point towards the ends, the expansion being taken up by the water rising in the upright



FIG. 349.

tube ends. Since these tubes take the surplus water, the full force of expansion is not exerted upon the pipe. Consequently, the pipe, if made of good material, will not burst. If, however, the ends of the pipe were plugged solid so that the expansion could not be taken up in them, the pressure in the pipe between the plugs would increase until it became too great for the pipe to resist, when it would either swell or burst.

991. Fig. 350 shows how a small quantity of water lying in a pocket of a lead pipe, which is otherwise supposed



FIG. 350.

to be empty, may by freezing burst the pipe. Ice forms on the surface of the water, first as at *A, A*, thereby sealing these points. Then the water underneath gradually freezes from the top downwards and around the inner surface of the pipe. This, of course, forms a gradually increasing

internal pressure, which at first may force the ice plugs outwards a little, but, as the plugs deepen, their resistance is increased. When they become sufficiently deep to resist a pressure equal to that required to swell the lead pipe, they remain stationary and the pipe swells and often bursts as shown at *C* in the figure. Lead pipes made of good material and of a uniform thickness will often stretch sufficiently to compensate for the increase in volume of the water or ice, but iron or brass pipes will not. While lead pipes will swell out and tear in the swelling only, brass and iron pipes will split with frost, sometimes even from end to end of the pipe.

THAWING FROZEN PIPES.

992. If the frozen pipes are accessible, and there is no woodwork around them which might catch fire, the gasoline torch may be applied directly to the frozen part of the pipe until the ice is thawed.

Pipes which are inaccessible may be thawed by steam, especially pipes which are under ground. To thaw out a service pipe which runs under ground to a street main, first disconnect the pipe just inside the cellar wall or shut-off cock. A tube of block tin, of about $\frac{1}{4}$ -inch bore, is then connected to the top of a portable steam generator, and as soon as steam blows, the tube is pushed into the end of the frozen pipe until it strikes ice. The steam will rapidly melt into the ice; the tube should be shoved forwards as fast as the ice yields until the stoppage is relieved. As soon as the water begins to flow, the tube is withdrawn and the connections restored.

The steam generator must be provided with a proper safety valve, adjusted to a safe working pressure. Otherwise it should not be used, because the danger of overpressure and explosion, with fatal results, is so great that no man is justified in running the risk.

Hot water may be used, sometimes, instead of steam, by using a hand force pump to drive the water to the desired point.

TEMPORARY STOPPAGE OF LEAKS.

993. During severely cold weather plumbers are often overrun with work, pipes freezing and bursting chiefly, and they can not always find sufficient time to make a permanent repair of the leaks; consequently they sometimes have to resort to a make-shift or temporary job.

A frost burst in a lead pipe (see Fig. 350) is seldom more than two or three inches long, although the pipe may be swollen its entire length. Therefore, a temporary patch can easily be soldered on it, quite strong enough to last till the plumber can put in a new piece of pipe. The burst is closed with a hammer, scraped, and soldered.

A frost burst in an iron or brass pipe, however, is not such a simple job. The burst takes the form of a split, which often runs the full length of the pipe. This requires a new piece of pipe. If, however, the split is only a few inches long, a temporary job may be made by smoothing the surface of the pipe around the split, then tying a strip of sheet rubber tightly over the split. The string or wire which binds it must be wound close to prevent leakage. Cast-iron soil pipes, if split, may be temporarily repaired in a similar manner.

CLEARING CHOKED DRAINS, ETC.

994. There are many ways by which drains become choked. If they have too little fall, and particularly if they are level or sagged in their middle, solid matter will gradually accumulate because of an insufficient velocity of the water whose duty it is to carry it forward to the point of outlet. The solid matter accumulates until the caliber of the pipe is entirely closed and sewage can not pass it. To clear such a choke, expose a part of the drain below the point of chokage (if no suitable cleaning-out holes can be found) and cut a hole in the top of it just large enough to allow the free working of the cleaning tools.

If the pipe is made of iron or brass, an iron wire or rod is commonly used to loosen the obstruction. The thickness

of the wire depends upon the character of the work. For ordinary obstructions in drainage work a $\frac{1}{4}$ -inch rod is commonly used. As the solid matter is disturbed by the rod or cane, the head of water in the drain above it will force it forwards to the point of outlet. The drain should then be thoroughly flushed, working the rod at the same time. To seal a hole that has been tapped in an earthenware drain pipe, the salt glaze all around the hole should be chipped off to a distance of about 2 inches. A sheet-lead flange is then beaten down over the hole to close it, and the hole sealed over with Portland cement. Cement will not take a strong hold of salt glaze.

995. Waste pipes, particularly those from kitchen sinks, are liable to become clogged with grease which passes into them in a liquid form combined with hot water. The grease chills within the pipes and adheres to them. Special brass screw caps should be attached to such pipes at points where access can best be had to them, so that rattan canes may be used to clear the obstruction if the pipes are made of lead, or iron rods or wire may be used if the pipes are of iron or earthenware.

Holes cut in lead waste pipes for the purpose of inserting the canes should be carefully covered over with a lead patch soldered on, not puttied.

Holes cut in iron waste or drain pipes should be sealed perfectly air-tight by clamps of suitable design, a rubber washer, not putty, being used to make the attachment air-tight.

Small chokages in waste branches are usually forced into the pipe stacks by force pumps applied at the fixtures. The force pump is composed of a cylinder about 3 inches in diameter, having a funnel-mouthed bottom with a rubber ring attached, to form a tight joint, and fitted with a solid piston or plunger. The small rubber force cups upon the market are mere apologies for force pumps; the quantity displaced at each stroke of the cup is too small to properly clear a chokage.

Vertical pipes seldom become choked unless there are

some bad obstructions, such as oakum driven through a joint, inside the pipe. Vertical pipes are cleared by inserting lengths of $\frac{3}{8}$ -inch or $\frac{1}{2}$ -inch gas pipe down from the roof. Care must be taken, however, that there are no offsets to intercept the rods.

Urinal waste pipes are very liable to chokage. The urine clogs against the sides of the pipes in the form of a thick slime. This can be removed by pouring strong muriatic acid down the pipe and loosening the slime with rattan canes. The ordinary force pump can not easily be applied to a urinal strainer.

VENTILATION OF WATER-CLOSET APARTMENTS.

996. When a water-closet is being used, an offensive smell is usually given off. This is partly taken away by the local vent (if any), and part of it will contaminate the air in the apartment. To remove the odor from the apartment it is necessary to remove all the air in the apartment. The frequency with which the air in the apartment should be renewed will depend upon how often the closet is used. The air may be changed in various ways. The most common way is to simply open a window at top and bottom. This causes a circulation between the water-closet apartment and the outer atmosphere. This method of changing the air, however, is only suitable for mild weather.

A 4 or 6-inch bright tin or galvanized iron pipe should be run from the ceiling just over the water-closet or near it, to above the roof, where its orifice should be guarded by a properly designed ventilator cap or cowl. The orifice of the tube above the closet should be funnel mouthed to 12 or 14 inches in diameter.

The tube should, if possible, be run up alongside a hot chimney flue, so that the air within it may be rarefied, and cause an upward draft. Advantage should be taken of the heat from burning gas jets in the apartment to facilitate the draft. This can be done by placing the light immediately under the funnel-mouthed inlet to the tube.

Dark water-closet apartments should in all cases be thoroughly ventilated, preferably by a tube, as explained, which has a gas jet burning within it or under it. The velocity with which the air travels up the tube will vary with the difference between the mean temperature of the air in the tube and the temperature of the outer atmosphere, also with the length of the tube and the number of bends, etc., in its length. In order to have the least resistance to the upward flow of the foul air, the pipe should be round or square in section, and should have as few elbows as possible.

When an exit is provided for foul air in the closet apartment, provision must also be made for an inlet of fresh air. This is best done by having a space of 2 or 3 inches between the bottom of the door and the floor.

Latrines, or a number of single water-closets in the same general apartment, are usually ventilated by one large ventilating tube run from the ceiling of the apartment. The closets are placed side by side with a 6 or 7-ft. partition between. The door of each closet, being hinged about 6 inches above the floor, forms the fresh-air inlet for the small space enclosed. The foul air rising upwards discharges into the upper parts of the general apartment and soon passes out through the ventilator. Whether ventilation is present or not, the odors of apartments which contain plumbing fixtures can be reduced considerably by proper attention being given to the fixtures. They should be scrubbed and cleaned often. If they are not attended to, odors will prevail in the apartments in spite of any ventilating system which may be installed.

DISPOSAL OF SEWAGE.

997. Sewage matter from buildings is disposed of in various ways, but chiefly by the following methods:

First—By a connection to the *main* or *street* sewer pipe or culvert.

Second—By cesspools.

Third—By direct or indirect discharge to the *sea* or rivers in close proximity to the building.

The **street-sewer** method is always adopted in well-regulated cities having a system of sewerage. For an ordinary residence the pipe leading to the street sewer, called the *sewer connection*, is generally 6 inches in diameter, and made of vitrified or salt glazed fireclay spigot and socket pipes. It should be laid in a straight line between the disconnecting trap in the cellar and the street sewer. A handhole should be attached to the pipe in the cellar, so that in case of chokage, iron rods can be run through to the street sewer. The point at which this pipe joins the sewer should, if possible, be sufficiently high up the sides that the sewage can not at any time back up in the sewer connections. The question of the disposal of sewage matter from buildings which are located in small country towns having no sewer system is sometimes a difficult one, especially when the water supply is taken from wells.

998. Cesspools are commonly used to receive the filth from sinks and privies; but they are so liable to foul the soil for many yards in every direction, to pollute the air, and to poison all the wells in the vicinity, that they should never be employed if they can be avoided.

It seems almost incredible that rational people should deposit their slops and excreta in a pit which is dug in the same stratum of earth which contains the well from which they take their drinking water; yet, this is one of the commonest hygienic crimes perpetrated in rural communities. The frequent epidemics of typhoid fever, diphtheria, and scarlet fever which have resulted from this practice have led the State Boards of Health in many States to prescribe that no cesspool or privy vault shall be built or maintained within 150 feet of a well which furnishes water for drinking or cooking purposes. Even this distance is so unsafe that the local Boards of Health are empowered in many States to forbid them altogether if they think best.

If the ground is composed of gravel or loose stones,

or coarse sand, the cesspool is generally built of loose stones without mortar, so that the water may filter away and leave the solid matter behind. The joints of the stones, however, soon become clogged with soap and grease, if the grease is not intercepted before reaching the cesspool, and the filtration is stopped. The cesspool then fills up and overflows.

If the ground is of a clayey nature, and no other method of disposal can be had, the cesspool will, of course, fill up, and it must be pumped out when full; the matter pumped out may be used as a fertilizer.

The cesspool should be dug as far as possible from the building, and should not upon any account be near a well, neither should the drain pipe leading to the cesspool be run near a well.

Cesspools should not be built air-tight, but should have a vent pipe discharging at a safe and proper distance from the house. A running trap also should be placed on the drain pipe near the cesspool, having a fresh-air inlet and vent cap attached, so that a constant current of fresh air may pass through the drain.

Filtration is a most unsatisfactory procedure. The glutinous sludge soon chokes every description of a filter.

999. If the sewage be **discharged into a river or the sea**, the outlet end should, if possible, be above high-water mark, so that high tides or rising of the river will not cause the water to flow up the sewer and perhaps choke it by backing up the solid matter. If the outlet must be below water mark, it should have a light brass flap valve attached, to prevent fish, etc., from entering the pipe. It should also have a relief or vent pipe attached at a convenient point to let out the air when a volume of water is passing down the drain or when water backs up.

Crude sewage should not be discharged into rivers or streams whose velocities are low and volumes small, or where the velocity decreases between the point of sewage discharge and the mouth of the river, such, for example, as

a deep or wide pool or dam in the river. As soon as quiet water is reached, the sewage matter will deposit there and putrefy and pollute the river.

Neither should the crude sewage discharge into the sea at points where natural currents can not be obtained to carry the solids seawards; because, if such a current cannot be obtained, the solid matter will be floated upon the beach and become a nuisance; or it will accumulate in mud banks and evolve offensive odors when agitated. The chief trouble to be found in discharging drains and sewers into the sea is that the sewage is *backed up* into the sewer twice in 24 hours. That is caused by the ebb and flow of the tide. This necessitates a good flush when the tide is low. The same trouble is experienced with tidal rivers.

1000. By the **irrigation** method the sewage is conveyed to a tract of land composed of sand or light loam, if possible, where it is spread over or through the ground and constitutes the food of vegetation so far as derived from the soil.

1001. There are many varieties of **chemical treatments** of sewage, but it is not within the limits of this Course to treat upon any of them. The motive for chemical treatment is to convert the sewage into a fertilizer, or otherwise dispose of it.

1002. The use of the **dry-earth closet** in place of privy vaults for the disposal of human excreta is rapidly extending among the more intelligent class of people. In this apparatus the excreta are covered with dry earth, preferably loam, or with the siftings of anthracite coal ashes. The ashes from bituminous coal are worthless for this purpose.

The quantity to be used on each occasion is about one quart, which is usually enough to absorb all of the liquids, and to neutralize all of the odors. The accumulations are received in pails, and are carried away at intervals to the garden or meadows as fertilizers. The sanitary advantages of this system are so great that it is likely to come into general use for outdoor closets for country homes.

SEWERS.

1003. Sewers for cities, towns, or villages are of two classes: the *separate system* and the *combined system*.

The **separate system** consists of two sets of drains, one to convey to a suitable and safe point of discharge all the water supply which, whether used for drinking, washing, or other purposes, is returned in a foul state as sewage. This pipe should be laid water-tight. The other drain is used only to carry away to some convenient watercourse all the rain or storm water falling or flowing upon the sewered districts. This drain need not be water-tight if the soil in which it is laid is wet, as it will thus drain the land when storm water is not flowing through it.

The volume of sewage from any town or city is practically a known quantity. It is nearly equal to the water consumption, if roof and storm waters are excluded. The volume of sewage changes slightly with the hours of the day, more flowing during the day than during the night. The sewage pipe should not be too large, but should be proportioned to the work it will have to do. Less fall will be required for it than for one which carries storm water combined with sewage, as there is no grit and sand to be washed forwards.

1004. The **combined system** is that in which the roof and storm water is conveyed to a suitable point of discharge by the sewers which convey the sewage from the buildings. The uniting of the two is claimed to be an advantage, since the storm waters flush the drains admirably.

Such sewers, if made large enough to carry off the heaviest thunder shower, are much too large for dry seasons. A small, shallow, sluggish stream of sewage will then flow through them, and solid matter is liable to accumulate, putrefy, and evolve *sewer gas*. If the sewers are constructed too small or have too little fall, they will fill up during heavy storms, and the water will back up into the basements.

1005. The shape which should be given to a sewer depends upon the nature of the flow through it. If the

quantity of liquid is fairly constant, a circular sewer or pipe may be used. If the flow is variable, as is always the case where storm waters are to be disposed of, the sewer should be egg-shaped.

The proper form to be given to an **egg-shaped sewer** is shown in Fig. 351. The upper part is a half-circle, having the diameter d . The total height h is equal to $1\frac{1}{2}$ times d . The bottom curve has a radius r , which equals $\frac{1}{4}d$. The sides are curved to a radius r_1 , which equals the height h .

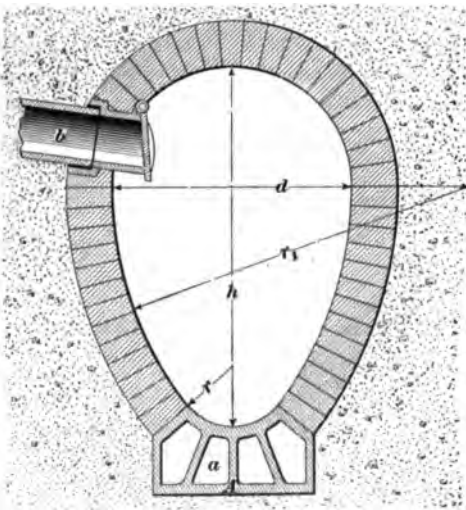


FIG. 351.

The special advantage presented by this form is that with a minimum quantity of water a maximum depth can be obtained, and that as the depth of the stream is diminished, the wetted perimeter, which is the friction-producing factor, is reduced proportionately.

The invert block A must be set upon a solid unyielding foundation. It is made of terra-cotta, salt-glazed on its inside face. The spaces a within the block may be used to drain the land. They form continuous channels to the sewer outlet.

The house drain b should join the sewer above the line d , as shown. If there is danger of water backing in the sewers, the orifice of b should be protected by a light-hinged flap valve, as shown.

1006. All sewers and drains should have open communication with the atmosphere at some point, so that air

may freely pass out and in to accommodate changes in volume of the liquid flowing through them, or to form a relief pipe for the escape of drain air should tidal water back into them.

Some sewerage systems are furnished with ventilating shafts located at their extreme highest ends. These ensure a constant current of air through the system, if the air in the shaft is warmer than the atmosphere. The natural ventilation of sewers and all underground drains is a current of air traveling towards their lower end, or outlet, during hot weather, and towards the ventilating shaft during cold weather, unless otherwise affected by prevailing winds, etc.

1007. Manholes should be built at every change of direction in a drain or sewer, for easy access, and at suitable distances along a straight sewer. They are usually built of good bricks laid in Portland cement and sand, and finished on top with a stone cover and strong cast-iron plate, laid flush with the ground or street.

Storm water and street washings should not flow directly into a sewer, as they carry large quantities of sand, sticks, etc. Such water should flow into a large **catch pit**, built after the principle of the pot trap. A very deep water seal should be made, as the water is subject to rapid evaporation. The catch pits are cleaned out periodically, and care should be taken to have the seal renewed after every cleaning.

The **velocity of the flow in sewers** and drains should not be less than 2 or 3 ft. per second, nor higher than 4 or 5 ft. per second, if the sewers are built of brick and convey storm water. If there is much sand or grit in the sewage, a velocity of 6 ft. or more is liable to wear away the brickwork.

The **fall of brick sewers** should be about 1 in 240 if possible, though with frequent flushing 1 in 600 may be permitted. When it is less than this, solid matter will deposit and requires to be removed by manual labor.

When it is impossible to obtain a suitable fall for sewers, so that the sewage may flow by gravity to the point of discharge, it is necessary to propel it forwards by mechanical means.

STABLE DRAINAGE.

1008. The waste water and urine from stables, etc., may be conducted away by gutters, which are sunk in the floor. These gutters are usually made of cast iron and are covered by perforated plates, which can be readily lifted off for cleaning purposes. The entire floor surface should be graded, so as to drain into them. The gutter *a* may be laid with an inclination of about 1 inch in 10 ft., and should empty into a surface trap and catch basin *b*, as in Fig. 352.

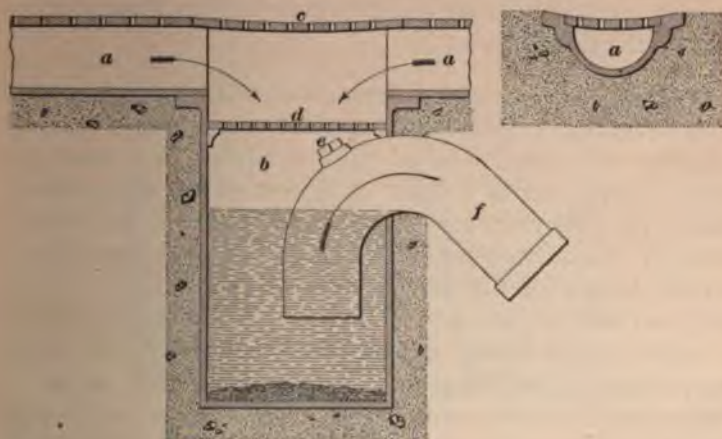


FIG. 352.

The solid matter will accumulate in the bottom as shown, and may be removed by lifting off the perforated covers *c* and *d*. Straw and such matter that might pass through the floor gratings is likely to be intercepted by *d*. A trap screw should be provided at *e*, through which rods may be inserted in case the pipe *f* becomes choked.

The clean waste water from the hydrants or drinking

troughs should, if possible, empty into the floor gutters at their highest ends, so as to flush and cleanse them.

CELLAR DRAINERS.

1009. Buildings, particularly those located on low ground, are often troubled with surface water accumulating in the cellars. If the cellar bottom be above the level of the street sewer or other convenient point of discharge, the surface water may be disposed of by gravity; but it is often found that the cellar floor is below the level of the street sewer, and so it becomes necessary to dispose of the water by some other means. Of course, it can be pumped out by a hand pump, but that requires attention and labor. An automatic and self-regulating contrivance, called an **automatic cellar drainer**, is often used, the power required to raise the water being water pressure from some source, such as the street mains.

1010. An automatic cellar drainer is shown in Fig. 353. It is operated by means of a small jet of water having sufficient pressure. The machine is placed in a small pit which is arranged to collect or receive all the water which enters the cellar. This may be made of an oak barrel, through which a number of holes have been bored and which is sunk flush with the floor or a little below it, or a brick well hole may be specially built for it. The supply pipe *a* is provided with a strainer in the flanged union *b*, to prevent the passage of anything which might choke the jet in *c*. The pressure water passes through the valve *d*, and issues from the nozzle *e* in a fine stream, about $\frac{1}{8}$ inch in diameter. The jet enters the cone *e* and carries with it a considerable quantity of the surrounding water which enters through the perforations in the cone *e*. The strainer *f* prevents the entrance of any matter which might choke the cone. The discharge pipe *g* extends upwards to a convenient height, suitable for discharge. The valve *d* is provided with a hollow stem of sufficient diameter to nearly fill the orifice. The water, after passing over the edge of the valve disk,

enters slots in the stem and emerges from small holes higher up the stem, as shown by arrows. This arrangement prevents the valve from dancing or chattering on its seat by causing it to fall under its own weight when it is but slightly open. The apparatus is started and stopped by the float ball *h*. As the water rises above a certain level, the float operates a finger *i*, which touches a collar on the valve stem and pushes the valve open. The valve remains wide open

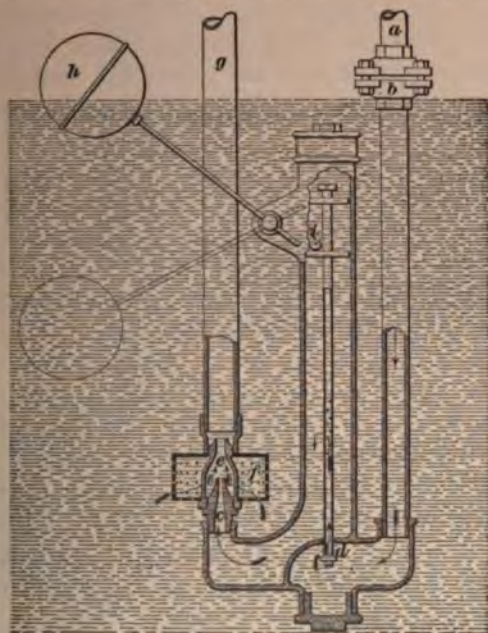


FIG. 353.

until the float falls to a lower level and causes the finger to engage the upper collar on the valve stem, and thus lift the valve to its seat. Thus the machine will start itself whenever the water rises high enough in the collecting pit, and will continue to eject water until the pit is nearly empty; that is, when the float has reached the downward limit. Where a supply of steam can be had, a common steam ejector may be used in a similar manner.

WATER SUPPLY.

METHODS OF SUPPLYING WATER.

1011. In the case of isolated buildings, such as country residences, the plumber is frequently called upon not only to provide fixtures and piping, but also to provide means for procuring water. A knowledge of the machinery which is available for that purpose is therefore necessary. In city houses machinery is used for pumping water into tanks on the top floors when the pressure upon the street mains is insufficient to raise the water high enough to properly supply the upper floors.

For raising water to a moderate height from wells or cisterns, say about 10 feet, **chain pumps** are to be preferred, because they agitate, and thus to some extent aerate the water. They can not be used for forcing, however, and when the lift is great, a piston or plunger pump must be used. To fix a pump in place the workman is sometimes required to descend into the well. All deep excavations in the earth are liable to become partly filled with carbonic acid gas, which is fatal to all animals, and kills by suffocating them. The well should be tested by lowering a lighted candle or lamp, on a wire or cord, to the surface of the water. If the flame burns badly or goes out, it indicates that gas is present in a dangerous quantity. This test should be made *every morning* before descending into the well. The accumulation of the gas is quite irregular, and it depends to some extent upon the pressure of the air as shown by the barometer. Sometimes a well which is free from gas upon a certain day will accumulate enough gas during a single night to be dangerous the next morning, especially if the weather is changing.

1012. Pneumatic pressure may be employed to force water to a building by simply forcing the water into a large closed vessel furnished with an inlet and outlet pipe so attached that the air will be locked in the vessel and can

not be forced out with the flow of the water. An arrangement similar to that shown in Fig. 354 will answer the purpose. An air-tight metal cylinder *A* having an inlet pipe *a* connecting it to the delivery pipe *b* of the force pump shown,

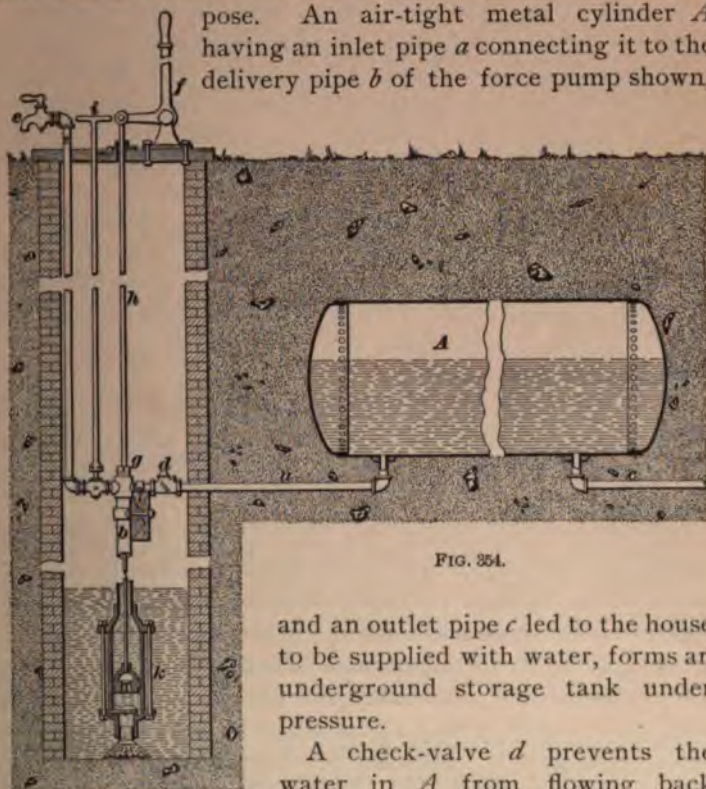


FIG. 354.

and an outlet pipe *c* led to the house to be supplied with water, forms an underground storage tank under pressure.

A check-valve *d* prevents the water in *A* from flowing back through *b* into the pump or out of the draw-off cock *e* above the surface of the ground. It will be seen that the plunger in the pump cylinder, which is under water in the well, is operated by the application of force to the handle of the bent lever *f*, the fulcrum of which is solidly bolted to a platform over the well. The pump shown is single-acting, and it raises water with the up stroke of the plunger. A stuffing-box at *g*, through which the plunger rod *h* moves, makes a water-tight joint.

A stop and waste cock on the pipe which supplies *c* can be operated by a T-handle key *i*. This is only for winter use to

shut off water from *c* and drain its supply pipe below frost. This plan of underground storage has the advantage of always keeping the water cool in summer and of storing it away where foul odors can not contaminate it. It has also two disadvantages: First, the pressure will be irregular, gradually decreasing as the water flows from the cylinder. Second, unless air be forced into the cylinder, that contained in the cylinder will soon be absorbed by the water.

1013. If a small stream of good water, having a fall of 5 feet or more, flows within a reasonable distance of the premises, a **hydraulic ram** may be used to great advantage to pump a steady supply of water into a suitable house tank. The principle upon which this machine is constructed is explained in Art. **615**.

These rams are also made double, so that they may be operated by a stream of dirty or impure water, but take pure water from some other source and elevate it to the point desired.

The drive pipes which are attached to hydraulic rams should be of wrought iron or brass, because the hammering of the water columns will rapidly destroy ordinary lead pipes. They should not be less than 30 or 40 feet long, otherwise the weight of the driving columns will be too small. If two or more rams are used, each must have its own independent driving pipe; but they may all discharge into the same delivery pipe. If angles or bends are necessary in any of the pipes, they should be made by bending the pipes to as large a radius as practicable. Angles should not be made with ordinary pipe fittings, because they seriously impede the movements of the water. To facilitate repairs each drive pipe and each delivery connection should be provided with a straight-way or gate valve.

1014. When **windmills** are employed for raising water it is especially necessary that the pumps, which are single-acting, be provided with extra large air chambers; otherwise the mill is liable to hammer itself to pieces, or make an unbearable amount of noise.

1015. Hot-air engines are very well adapted for pumping purposes. They require very little attention and use but little fuel. Care must be taken to avoid overheating them, and to keep them properly lubricated. If the engine is of the vertical type, the engine house roof must be made high enough to permit the removal of the pistons by means of a block and tackle. There should be a hatch in the roof large enough to allow the pump rods and tubes to be lifted out of the well.

1016. Another type of engine which has been recently perfected is the **oil engine**. This machine uses a small quantity of mineral oil, of any grade, from crude petroleum to gasoline. The oil is changed to a vapor which is exploded in the cylinder of the engine. For equal power they are much smaller in size than hot-air engines. There is no danger connected with their use, except that which arises from the presence of the oil tank upon the premises. They require a certain amount of cooling water to be circulated through them. Usually the water which is pumped by them can be used for cooling, without objection. They can be used anywhere, and can be operated by almost anybody.

1017. In towns where gas or electricity can be obtained, **gas engines** or **electric motors** may be employed to good advantage for pumping purposes.

1018. For hotels and other places which require a large amount of water, the **steam pump** is probably the best machine that can be employed.

1019. The amount of water which is actually required per day has been found by measurement to be about 25 gallons for each person, large or small.

This amount is approximately made up as follows:

1 quart for drinking.

1 quart in food.

1 gallon for washing dishes and cooking utensils.

2 gallons for housecleaning.

3 gallons for washing clothes.

5 gallons for toilet purposes.

The remainder is used for bathing and water closets.

A horse will drink about 7 gallons per day, and will need 4 gallons for washing.

A carriage will require from 9 to 16 gallons for washing.

A cow will drink 5 to 6 gallons per day.

THE ERICSSON HOT-AIR ENGINE.

1020. In Fig. 355 is shown a general view of the

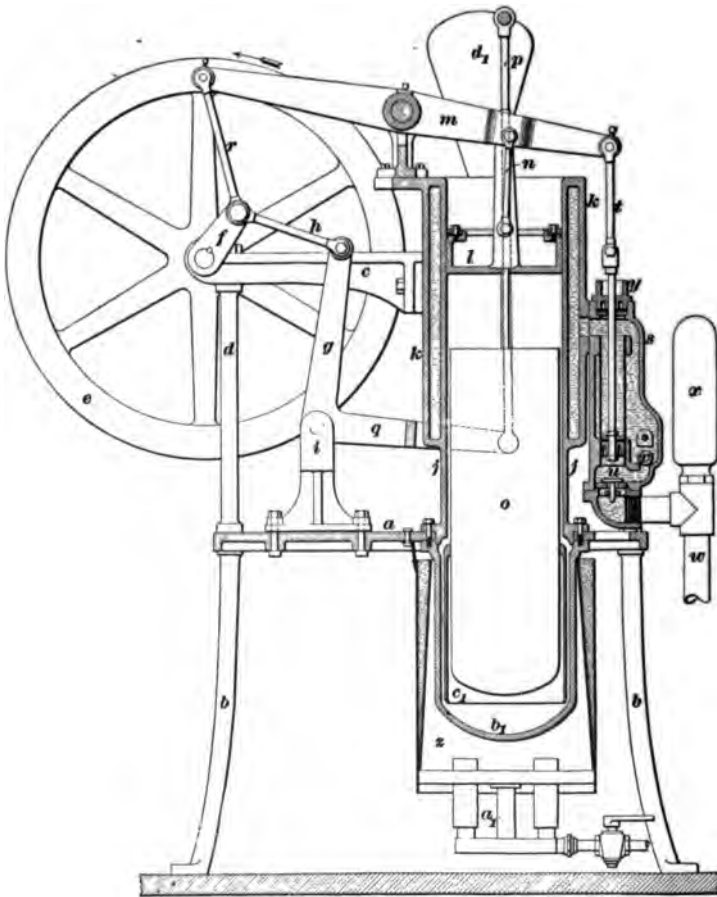


FIG. 355.

Ericsson hot-air engine. This engine is chiefly used in connection with a low-duty pump, and may be had with the fire chamber adapted to any class of fuel. The style shown is designed to use gas as a fuel, and is very suitable for use in city buildings where city gas is easily obtained, or in suburban or country buildings having their own gas-making machines.

The engine is composed of a solid iron rectangular frame *a* supported by four wrought-iron legs *b, b*, solidly bolted to the floor. A cast-iron bracket *c* and a wrought-iron post *d* support a fly-wheel *e* which has a crank *f* attached to its axle by a keyed joint. The power arm *g* of the bent lever, or bell-crank, whose fulcrum is *i*, engages with *f* by means of a connecting link *h*. A cast-iron cylinder *j*, having a water-jacket *k* around its upper part, is fitted closely with a main piston *l* connected to an overhead lever *m* by connecting links *n*. The cylinder is fitted loosely with a transfer piston *o*; this piston is connected to a rod *p* which branches out over the walking beam *m*, and passing down outside of the water-jacket connects on the weight arm *q* of the bent lever, as shown by dotted lines. One end of the walking-beam engages with *f* by means of a connecting link *r*; the other end engages with the piston rod of a pump chamber *s* which is bolted to the water-jacket by means of a brass connecting link *t*. The form of pump shown is usually furnished with the engines, being specially designed for them. The pump shown is single-acting, and the plunger moves in a brass cylinder within the pump chamber *s*, as shown. The foot valve *u* is simply a disk of rubber held in place by a brass bolt. The outlet or discharge valve *v* is a right circular cylinder of rubber resting loosely on an oblong seat. The suction pipe *w* is connected to the source of water supply, either a shallow well, cistern, or city water mains. It is customary to place an air chamber *x* upon the pipe *w* and near the pump. A brass gland and nut at *y* holds the pump rod packing in place. The furnace *z* is composed of a double thickness of heavy sheet iron having insulating material between, and is fitted with a sheet-iron pipe to convey the

products of combustion to some convenient chimney. In the figure the furnace is shown fitted with atmospheric gas-burners a_1 of the Bunsen type. Atmospheric gas-burners are described in the section on Gas and Gas Fitting. A lever handle stop-cock is attached to the gas supply pipe, and a screwed union is placed on the pipe between the burner and the stop-cock, so that the burner may be taken out at any time. The cast-iron heater b_1 , which is a cylinder with an elliptical lower end, hangs in the combustion chamber or furnace, and is supported by bolts which attach it to the upper cylinder j by an air-tight joint. Another cylinder, or sleeve, c_1 is suspended within b_1 in such a manner that communication is had between the spaces above and below the transfer piston.

1021. When the heater is sufficiently hot (its working temperature, of course, varying with the work the pump has to do, but usually a dull red heat), the fly-wheel is revolved by hand once or twice to start the engine. When at work, the heater b_1 is kept at a dull red heat. As the parts are shown in the cut, the piston l is very near the lower end of its stroke, and the plunger or transfer piston o has made about one-third of its upward stroke. As it approaches l , the air between them is driven downwards, between o and j , into the space underneath. As the air passes over the red hot surface of b_1 , it is quickly heated and expanded. The pressure which results from the expansion drives the piston l upwards and rotates the fly-wheel. About the time that l reaches the middle of its stroke, the plunger starts downwards, and quickly displaces the air in the hot lower end of the cylinder, driving it into the upper and cold end. As the air comes into contact with the water-cooled surfaces of the cylinder, it parts with its heat to the water and contracts correspondingly. The pressure decreases sufficiently to permit the fly-wheel to return the piston to the lower end of its stroke without stopping, and to move the plunger, thus shifting the cooled air into the heater again. The pressure

of the air within the cylinder thus rises and falls once during each revolution.

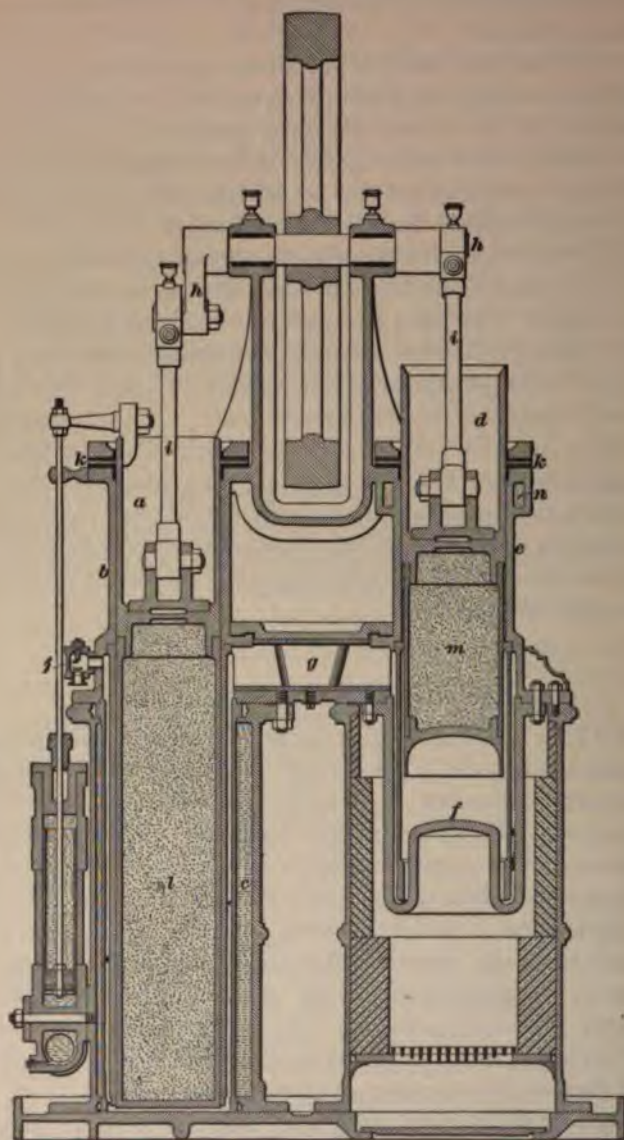
It will be seen that the air when expanded by the heat of the fire, forcing the piston *l* upwards, also raises the pump plunger, which forces a certain quantity of water through the water-jacket and into the delivery pipe connected to it. A copper air chamber *d*₁ is attached to the delivery pipe near the water-jacket, and forms a cushion to receive sudden shocks which might otherwise burst the outer shell, or jacket.

The student will observe that all the water raised with this engine must pass through the water-jacket and do duty as a cooling medium. He will also observe that only the up stroke of the pump raises the water. To stop the engine it is only necessary to shut off the gas.

When it is necessary for the pump to raise water to a height greater than 100 feet, such as is often the case in country buildings, a double cylinder hot-air engine is most commonly used. With this class of engine, coal is generally used as the fuel, although furnaces can be had which will burn any kind of fuel.

THE RIDER COMPRESSION ENGINE.

1022. In Fig. 356 is shown a **Rider compression engine**, especially designed for heavy-duty pumping. Although composed of two cylinders, its principles of action are nearly the same as the Ericsson, already explained. The compression piston *a* extends down into the base of the engine, and closely fits the cylinder *b* and a sleeve suspended from it which extends down to about $\frac{1}{2}$ inch from the bottom, as shown. An air space, in the form of an annular passage, is provided between this sleeve and the cooler, or water-jacket *c*. The power piston *d*, which fits the cylinder *e* closely, extends down into the heater *f*, and closely fits the top of a sleeve suspended from *e*, and which extends down into the annulus of the heater, as shown. Annular air passages are formed around the power piston and the sleeve. The air space within the heater



communicates with the space enclosed by the water-jacket *c* by means of a regenerator *g*, fitted with a number of thin plates held apart about $\frac{1}{8}$ of an inch. The pistons *a* and *d* engage with a fly-wheel and axle supported by cast-iron brackets, as shown, by means of cranks *h* and connecting-rods *i*. An arm bolted to the top of the compression piston connects with the plunger rod of the pump. A snifter valve *j*, whose action is similar to a vacuum valve (see Art. 765), furnishes air to the interior of the compression chamber, if at any time the pressure therein becomes less than that of the atmosphere.

Double cup leathers are secured at *k* to make the pistons air-tight around their top. Any leakage of air at these packings or elsewhere is compensated for by a supply of air through *j*. The furnace pot of this engine is lined with thick firebrick, and a 6-inch or 7-inch smoke pipe is taken from the back of the combustion chamber if coal is used as the fuel. In operation the heater is maintained at a low red heat. When the parts are in the position shown, the greater part of the air is in the heater and is expanding, thus driving the piston *d* upwards. During the last half of its upward stroke it is assisted by the pressure which acts under the piston *a*. By the time that the piston *d* has reached the middle of its downward stroke, the plunger *a* has risen to the top of its stroke, and the greater part of the air has been driven through the regenerator into the cooler. The pressure rapidly falls and permits the fly-wheel to drive *d* to the bottom of its stroke. Meantime *a* comes half-way down and compresses the charge of air. As *a* continues to move downwards, *d* begins to rise, and the transfer of the cooled air to the heater begins. Thus the pressure rises and falls within the engine during each revolution. In the passage of the hot air from the heater to the compression cylinder, a large amount of heat that has been absorbed and retained by the regenerator plates is transmitted to the air on its passage back to the heater. Thus it will be seen that the regenerator is a very economical feature. The pumps used in this class of engine are double acting.

The lower parts *l* and *m* of the pistons, which are subject to high temperature, are filled with non-combustible, non-conducting material. The packings *k* on top of the cylinder *c* are kept at a low temperature by a water collar *n*, through which a stream of water is allowed to flow while the engine is working. The water-jacket *c* is connected to *n* by a $\frac{1}{4}$ -inch iron pipe having a stop-cock in it to regulate the flow. The surplus water passing through *n* is usually allowed to go to waste. It is only a very small stream, forming a mere fraction of the quantity of water delivered by the pump.

Care must be taken when oiling these hot-air engines not to allow oil to flow into the cylinders, as it soon becomes baked hard and fast, and finally stops the engine by jamming the pistons.

These engines must be set upon a solid foundation, preferably a concrete floor, and the base should be bolted to the floor. They must also be set perfectly plumb, so that the pistons, which are very heavy, will bear equally all around.

Care must be taken also to avoid overheating the heater cylinders. They are liable to crack if they are heated too highly or unevenly.

These engines are specially adapted for heavy pumping where unskilled labor is employed to run them.

WATER METERS.

1023. Water meters are used to measure the quantity of water which passes through the service pipe to the building.

The requirements of a good meter are that it shall measure accurately *all* the water which flows through it, whether it passes as a very small stream, or is of the full capacity of the pipe. The working parts should be durable, so that the accuracy of the meter may be maintained for a long period. The meter should offer as low a resistance to the flow of the water as possible.

Meters should always be set level, to secure proper oper-

ation of the working parts. They should be placed on the main service pipe, close to the point where it enters the premises, with a waste cock on the side next to the mains, so that the water may be drained from it when desired. An air chamber of generous size should be attached to the service pipe close to the meter, upon the inlet side, to absorb all the shocks that occur in the pipes.

1024. The meter must be placed so that the dials can be readily observed. The method of reading the dials is about the same in all kinds of meters. Fig. 360 shows the ordinary arrangement. The figure to be taken is always that one which the pointer has last passed, not the one which it is approaching. The figure which is indicated upon the dial, marked 10, must be put down first; that is, in the **units** place. To the left of it put down the figure indicated upon the dial marked 100; to the left of that put down the figure indicated upon the dial marked 1,000, and so on. Thus the dials in Fig. 360 indicate 6,417 cubic feet. The small dial marked **one foot** indicates only fractions of a cubic foot. To find the quantity of water which has passed through the meter in any certain time, subtract the previous reading from the later one.

Great care must be taken to protect the meter by means of a fine strainer from the entrance of fish, sand, etc. The working parts are usually made of hard rubber, which is quickly destroyed by *hot water*. If there is any danger of hot water flowing back from the boiler to the meter, a meter should be used which has its working parts made of brass or bronze.

The accuracy of a water meter may be tested by weighing the water which passes through it. Several tests should be made, drawing the water slowly in some tests, and as rapidly as possible in others. An ordinary barrel will hold about 5 cubic feet, or between 350 and 400 lb. of water, and is of convenient size for this purpose.

There are many varieties of water meters upon the market; a few of the most common are as follows:

1025. The **piston meter**, having two reciprocating pistons working in suitable water barrels; if well constructed, it is an accurate machine. The **Worthington** is a good representative of this class.

1026. The variety shown in Fig. 357 is a **rotary piston meter**; this has

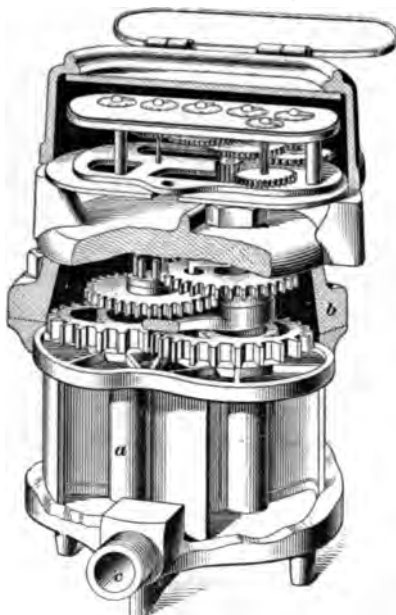


FIG. 357.

two revolving cylinders *a*, provided with wings which roll together in such a manner that no water can escape past them without being measured. The elliptical gears in the chamber *b* prevent the pistons *a* from becoming locked. Each revolution of the pistons allows a certain definite amount of water to pass, and the registering apparatus in the top chamber is so constructed that it will show the gross amount in cubic feet. The meter is attached to the pipe by a

coupling connection at *c* and by a corresponding connection on the opposite side.

1027. The **disk meter** is shown in Figs. 358, 359, and 360. The disk *a* in Fig. 358 is attached to a central ball *b*, which rocks in suitable bearings in the top and bottom heads *c*. These heads are conical, and the sides of the chamber in which the disk moves are truly spherical. A top view of the disk and working chamber is shown in Fig. 359; the water enters at *a* and passes out at *b*, the outlet being divided from the inlet by a partition *c* which extends from the upper to the lower head, and from the ball to the side of the chamber. The disk is slotted to fit over this partition.

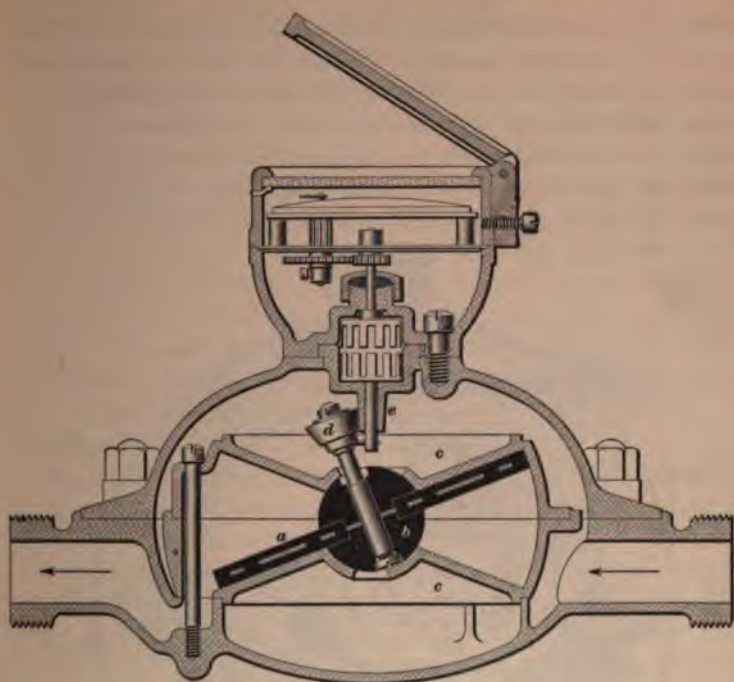


FIG. 358.

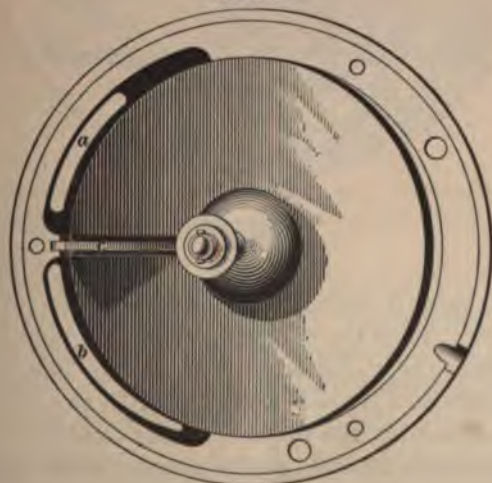


FIG. 359.

The roller *d*, which touches the stud *e* central with the spherical chamber, compels the disk to always touch the upper and lower heads. Since the heads are frustums of cones, and since the disk is a flat plate, it follows that the latter is in contact with the upper and lower heads only along a single line. Referring to Fig. 358, which is a section taken through the outlet port *b*, Fig. 359, let the disk



FIG. 300.

be depressed until it occupies its lowest position in front of the *inlet* port. Then the disk will touch the upper head just about opposite the partition *c*, Fig. 359. The inflowing water fills the space from the inlet port to the line of contact of the disk with the upper head; it tends to force the disk away from the latter. But since the roller *d* prevents this, the disk gyrates; i. e., rolls along the conical surfaces

of the heads. As the disk keeps on rolling, it soon opens the outlet port, the momentum of the water on the *under* side of the disk forcing the water on the upper side of the latter out into the outlet port. The disk is now, in reference to the inlet port, in its highest position; hence, touches the lower head just about opposite the bridge *c*, Fig. 359. The inflowing water tends to force the disk from under the head now; but since this can not take place, the disk gyrates in the same manner as before. Thus, it is seen that at alternate gyrations the inflowing water is above and below the disk; hence, the outflowing water is discharged alternately above and below the disk. Each gyration of the disk displaces the entire contents of the chamber, and this quantity is registered on the dials above, in cubic feet.

Red or white lead should not be used in screwing up joints in meter connections, or the pipe which joins the meter to the source of water supply, because some of it is liable to reach the interior working parts and clog their movements.

All meters must be carefully protected from frost.

SIZE OF WATER PIPES.

1028. The proper diameter of pipes which are to supply hot or cold water depends upon several considerations:

1st. The number and size of faucets which are likely to be discharging water at the same time.

2d. The pressure or head of the water.

3d. The length of the pipe.

If the pipe is crooked, making numerous bends or angles, due allowance must be made for the resistance arising therefrom.

A pipe of small bore having great length is likely to be noisy, if the pressure is great, being subject to singing noises and water hammer. This defect may be avoided by using a pipe of larger diameter, thus reducing the velocity of the moving water.

1029. **Horizontal pipes** may be reduced in diameter as various branches are taken off. This is done only to

economize in the cost of pipe, etc. An example of such reduction is shown in Fig. 361. In this the nearly horizontal

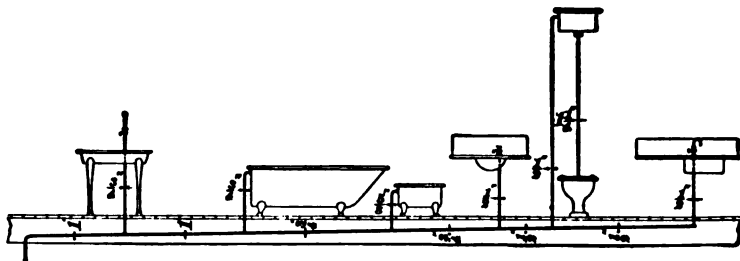


FIG. 361.

distributing pipe is reduced from 1 inch to $\frac{1}{2}$ inch as the branches are taken from it.

Suppose that the distributing main should enter at the opposite end so that the pantry-sink branch would be taken off first, then it would only be reduced one size, that is, from 1 inch to $\frac{3}{4}$ inch, because its extreme end must equal that of the sink branch. It is well to have the distributing mains a little too large rather than too small; the annoyance of one faucet robbing another will then be avoided.

1030. Vertical pipes which descend from a tank may be reduced in a similar manner, as shown in Fig. 362. The tendency of the water flowing from the tank *A* is, of course, to fall to the bottom of the vertical line of pipe, and flow out of the lower branch. Although the vertical line is decreased in size as it descends, it still follows that there is a greater pressure upon the lower branches than upon the higher; and to compensate for this difference in pressure, the sizes of the branches upon the different floors should be decreased as they descend. Thus, in the figure the top branch is 1 inch and the lowest $\frac{1}{2}$ inch. By this system of distribution a nearly uniform supply of water can be given to each floor in a high building.

1031. Pipes which rise from a service pipe in the basement and ascend to the upper stories usually should not be reduced in diameter until the last branch is reached. This

is because the pressure grows less as the height increases, and to secure a satisfactory flow on the upper floors, the pipes must be large in diameter. Even if the head is so great that there is plenty of force on the upper floors, if the pipes be reduced in diameter, they will be liable to annoyance from the action of the faucets in the lower stories. If a faucet in the basement be opened, for example, the flow from a faucet on the top floor, which happens to be open at the same time, will be checked or even stopped.

The size of the corporation cock which may be attached to a street main is usually determined by the water department. The diameter of the service pipe should not be governed by the size of the corporation cock, however, but should be determined solely by the requirements of the building. If the quantity of water required is very large, the water authorities will, upon due presentation of the facts, usually allow a larger connection to be made to the water mains.

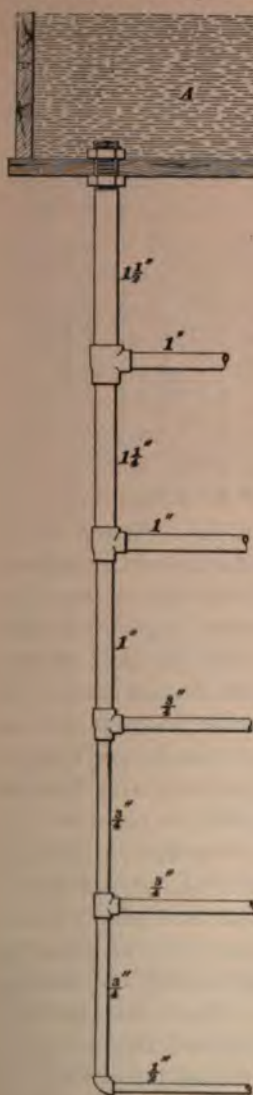


FIG. 302.

1032. The following **sizes of branches** are commonly used in buildings where the pipes are not of great length. If the pressure is less than 20 lb. per sq. in.,

the system may be rated as *low pressure*, and if above 20 lb., as *high pressure*:

TABLE 39.

Supply Branches.	Low Pressure.	High Pressure.
To bath cocks.....	$\frac{3}{4}$ to 1"	$\frac{1}{2}$ to $\frac{3}{4}$ "
To basin cocks.....	$\frac{1}{2}$ "	$\frac{3}{8}$ to $\frac{1}{2}$ "
To W. C. flush tank.....	$\frac{1}{2}$ "	$\frac{1}{2}$ "
To W. C. flush valve.....	1 to 1 $\frac{1}{4}$ "	$\frac{3}{4}$ to 1"
To sitz or foot baths.....	$\frac{1}{2}$ to $\frac{3}{4}$ "	$\frac{1}{2}$ "
To kitchen sinks.....	$\frac{5}{8}$ to $\frac{3}{4}$ "	$\frac{1}{2}$ to $\frac{5}{8}$ "
To pantry sinks.....	$\frac{1}{2}$ "	$\frac{3}{8}$ to $\frac{1}{2}$ "
To slop sinks.....	$\frac{5}{8}$ to $\frac{3}{4}$ "	$\frac{1}{2}$ to $\frac{5}{8}$ "
To urinals.....	$\frac{5}{8}$ to $\frac{3}{4}$ "	$\frac{1}{2}$ to $\frac{5}{8}$ "

PURIFICATION OF WATER.

1033. The impurities which occur in ordinary waters are of two kinds; viz., mechanical, or those held in suspension by the water, and physical, or those held in solution. The mechanical impurities are mud, leaves, vegetation, fish, frog spawn, insects, insect eggs, etc. The physical impurities are solutions of minerals, putrescent animal matter, albuminous slimes, etc. The leachings from privy vaults and drains are the most harmful poisons that usually get into the water supply. The mechanical impurities are far less dangerous, being easily seen and quite easy to remove.

Nearly all mechanical impurities can be removed by filtration through sand or other suitable material, but the danger lies mainly in the matter held in solution and which is consequently invisible. Mineral poisons can be neutralized by the use of chemicals, and sometimes by heating and settling or by distillation. The organic poisons from sewage, etc., can only be entirely removed by distillation, but a careful repeated filtration through sand and bone charcoal will, in most cases, improve the water sufficiently to make it suitable for drinking and cooking purposes. Bone charcoal is often employed as a filtering medium, because it exerts a

chemical action upon the organic matter in the water, and renders it inert or harmless. The charcoal, however, gradually becomes saturated and clogged with the refuse, and loses its value as a purifying agent. Therefore, it must be renewed at intervals.

Bone charcoal is hard and dense, and when its pores become clogged with refuse it can be restored to usefulness only by reburning. There is no practicable way by which this can be done upon a small scale. Unless the air is carefully excluded during the whole process, the material will be consumed, like other charcoal, and will be destroyed.

Charcoal which is made from wood has little or no value for the purpose of filtration.

Water which has grown stale by standing may be greatly improved, and be made suitable for drinking purposes, by the process called *aeration*, provided it has not been otherwise polluted.

1034. Aeration may be accomplished in several ways. The water may be squirted into the air in fine streams, air may be forced through the water in fine bubbles, or air and water may be shaken up or otherwise agitated together. The object to be attained in every case is to expose the water to the action of the air to the greatest practicable extent.

In the process of aeration the water absorbs a considerable quantity of air and is thereby greatly improved in appearance and taste. The air has a mild oxidizing effect, which is sufficient to destroy a small amount of vegetable matter and render it harmless. But this purifying influence is very limited in extent, and is of no use whatever for removing or destroying the germs of putrefaction, fermentation, and disease which are imparted to the water by sewage or house drainage. These germs can be killed only by boiling, and in the case of certain disease germs even boiling is insufficient; they can be completely destroyed only by fire.

The process of aeration is thus adapted only to the purpose of *freshening* water and rendering it more palatable, and is not serviceable for actual purification.

In all apparatus designed to aerate water, care must be taken to thoroughly exclude all dust from the air, because dust is very apt to carry with it many kinds of germs which give rise to putrefaction and disease. Dust must be kept out of food and drinking water.

1035. Rain-water which is taken from the roofs of buildings is always more or less contaminated with leaves, dust, excreta of birds, dead insects, etc. If it is desired to use any of this water for drinking or cooking purposes, the pipes which lead it to the cistern, or the cistern itself, should be supplied with a device called a **rain-water cut-off**. This is an apparatus which turns all of the water from the rain leaders to waste until the roofs are washed clean, and then turns the water into the cistern. The water which falls during the first few minutes of a rain-storm is loaded with dust and insects, but after twenty minutes or so it is usually very pure.

FILTERS.

1036. In all varieties of filters the velocity of the water passing through them should be low enough to permit the finest sediments to deposit themselves upon the surface of the beds of filtering material. Otherwise, in treating muddy water, it will retain a muddy color.

The velocity of the water passing through a filter bed of bone charcoal should also be low, so that the water may be in contact with the charcoal as long as possible, the chemical changes in the impurities thereby being more complete. The filtering material becomes gradually clogged by the accumulation of refuse matter upon the surface of the bed and upon the grains of sand or charcoal; the flow of water is checked and the usefulness of the apparatus is greatly impaired. This can be remedied, however, by *reversing* the direction of the flow of water at suitable intervals. Thus, the accumulations can be washed away and be run to waste, and the filter can be operated almost continuously.

A filter which can not be thus reversed should not be employed if it can be avoided, because the care and trouble

which will be required to keep it in good working order will be so great as to lead to almost certain neglect. A filter which is neglected is apt to become foul, and thus give rise to the very danger that it is intended to prevent.

There are so-called filters which are made to screw upon the nozzle of an ordinary faucet. They consist of a cup having a filling of bone charcoal or other filtering material, and they operate only as strainers, to hold back the insoluble impurities which are carried by the water. They do not purify the water except in a mechanical way. The bone charcoal has no purifying effect, because the water passes through far too rapidly for any chemical effect to take place.

Filters should be kept full of water. They should not be allowed to become dry nor to be exposed alternately to water and to air. Alternate wetting and drying of putrescible matter greatly hastens putrefaction and increases the growth of disease germs, etc. A filter which is thus operated is liable to become a source of poison instead of a protection against it.

In cities and towns having a water supply which is liable to become muddy at times, dwellings should be supplied with a filter located in the basement. All of the water which enters the house should pass through the filter. This will prevent the kitchen boiler from filling up with mud, and will ensure clean water throughout the building.

1037. The mode of constructing an ordinary filter, suitable for rain-water, etc., is shown in Fig. 363.

The body of the filter is built of brick, laid in mortar composed of Portland cement mixed with an equal volume of clean, sharp sand, and it is divided into two chambers by means of a partition slab *a* of slate or flagstone. The bottom of chamber *A* is provided with a low place or pocket *d*, in which may gather sediment and from which it may be removed by the garden pump or other convenient means. The chamber *B* is fitted with a perforated bottom *b*, upon which is placed a course of gravel, then clean sand, nearly

up to the level of the discharge pipe *f*. It is then topped with gravel. The rain-water enters chamber *A* through the pipes *c, c* and deposits any solids that may accompany it into the pocket, as shown at *d*. It then flows upwards through the sand in chamber *B*, which clarifies it. Chamber *A* is also provided with an overflow pipe *e*, so that if the filter becomes choked with dirt, the water will not acquire

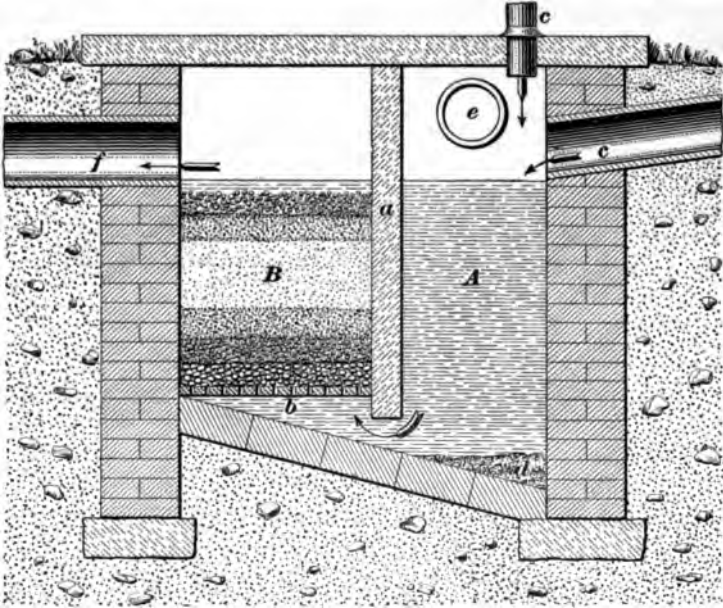


FIG. 369.

sufficient head to force the dirt through the filter; it also acts as an overflow for the cistern into which *f* delivers.

LOCATING FIXTURES.

1038. Fixtures should be so located in a building that the pipes necessary to supply them with water, and carry off the discharges from them, shall not be run in exposed walls; although in many cases it is safe to run the pipes against the walls, if the pipes are open to the warmth of the

room. They should be located in places where light and ventilation are abundant.

Sinks and washtubs should be located as near the windows as possible.

Water-closets, baths, etc., should not be placed too near windows in cold climates, because there is always a cold down draft near a window, and persons using these fixtures are liable to catch cold by being in contact with the draft while undressed.

Hot-air registers should not be permitted in the floor immediately in front of a water-closet, because a current of hot air (which usually can not be entirely stopped) is disagreeable to the person using the closet.

The fixtures should all be located with a view to the general convenience of the parties who will use them.

Thus, the cook's sink should be placed convenient to the kitchen range, yet far enough away to be unaffected by heat radiated from the range or from the boiler.

The dish-washing or scullery sink should be placed convenient to the dining-room and kitchen.

The laundry tubs should be convenient to the back yard, or drying room, as the case may be. If located in basements they should be placed in front of the windows, so that the best light possible may be obtained upon the work. The butler's pantry sink should be conveniently near the dining-room, preferably between it and the kitchen.

The water-closets, baths, and wash basins should be convenient to the bedrooms. If wash basins are to be placed in bedrooms, care should be taken to place them as far away from the beds, yet as near to the light, as possible, and near the vertical waste stacks into which they will discharge, so that long branch waste pipes may be avoided.

Slop sinks should be placed at points convenient for drawing off water for bedroom urns, etc., and for receiving bedroom slops.

A water-closet arranged for servants' use should be located on the ground or basement floor, because most of the servants' time is spent in the lower part of the building. No

fixtures should be located in dark or unventilated closets, particularly those in the center of a building, because odors from the closets will diffuse throughout the building and become a dangerous nuisance.

Fixtures on the several floors of tall buildings should be arranged over one another as much as possible, and clustered in vertical rows, so that short branch wastes will be required to connect them to a soil-pipe stack common to them all.

Fixtures should not be set over parlors, dining-rooms, libraries, or other rooms having valuable furnishings or decorated ceilings, for a leak is liable to do great damage; they should rather be located over kitchens, sculleries, pantries, closets, etc., so that a leak will do little damage. The soil and waste-pipe stacks should not be run in walls adjoining living rooms, because the sound of water falling down these pipes is disagreeable.

SYSTEMS OF PLUMBING AND DRAINAGE.

1039. The student having now become familiar with the principal details of plumbing and drainage systems, we will proceed to illustrate, by the following figures or plans, how the several parts when properly fitted up form what are known as **plumbing and drainage systems**, or, more properly speaking, systems of house drainage and systems of water supply and distribution.

The systems shown, although they do not cover the entire field of house plumbing and drainage, are so arranged as to show clearly to the student what is considered good modern practice in the United States of America. We advise the student to carefully study these drawings until he fully understands the use of every pipe and fixture shown. He should experience little difficulty in reading the drawings if he has retained what he learned while studying the preceding sections.

PLAN NO. 1.

OUTSIDE HOUSE DRAINAGE.

1040. Fig. 364 shows by plan and sectional elevation a system of drainage suitable for an isolated building. Water is assumed to be scarce, and the rain-water falling upon the roof of the building is collected and stored in a brick and cement cistern. The sewer pipe is supposed to be very long, and to have a very slight fall towards its outlet. To keep the drains clean with a minimum expenditure of water, the waste water from some of the baths and wash basins is collected in an automatic flushing tank and discharged periodically for flushing purposes. Of course, when this is done, the bath and basin stacks must be carried separately up to and through the roof, and have no connection with the closet, soil, or vent pipes. It will be noticed that all the pipes are run immediately through the main walls and underground. This avoids running horizontal pipes in the basement or under the floors of the building, thereby reducing the danger from leaks to a minimum.

The building is shown in block plan, its main walls being shown at *A*.

The 6-inch earthenware pipe *a* is the house sewer proper. It conveys all of the sewage from the building to a suitable outlet. The main disconnecting trap *b* is built in a brick manhole. An inspection piece into which the drains *d* discharge, and the fresh-air inlet *c* joins, delivers into the trap. A closed inspection piece is built into the manhole *f*.

An automatic flushing tank *g* is connected to the highest end. This receives discharge from the bath and basin waste *h*. The pipe *i*, led to a convenient point, is a fresh-air inlet to *g*, while *h* acts as an outlet.

A grease trap *j* intercepts grease, etc., from the sink *k* and laundry tubs *l*, and is ventilated to the roof by a 3-inch pipe *m*, a few holes being made in the cover for an air inlet.

The branch drains *d*₁, *d*₂ connect the soil-pipe stacks *n*, *n* to the main drains. The discharge from baths and basins connected to the waste stack *h*₁ enters the drains direct.

The roof water falls in the leader or conductor pipes *p* into the selected stoneware rain-water pipes *q*. These pipes convey it to the filter *r*, through which it must flow before entering the cistern *s*, from whence it is drawn to the building by a pump attached to the suction pipe *t*. An overflow for the filter, that is, for the cistern, is shown at *u*.

The trap *v* disconnects the flushing tank from the drains, so that when the tank is empty it will not be flooded with drain air.

A small air pipe, which turns over in the tank *g*, prevents air lock between *g* and *v*. A handhole *w* is placed upon the drain for easy access.

Should the water supply to this building be abundant and the roof water permitted to flow to waste, the best method then would be to run all the rain-water drains into a flushing tank, and all the discharge from the several pipe stacks into the drainage system direct.

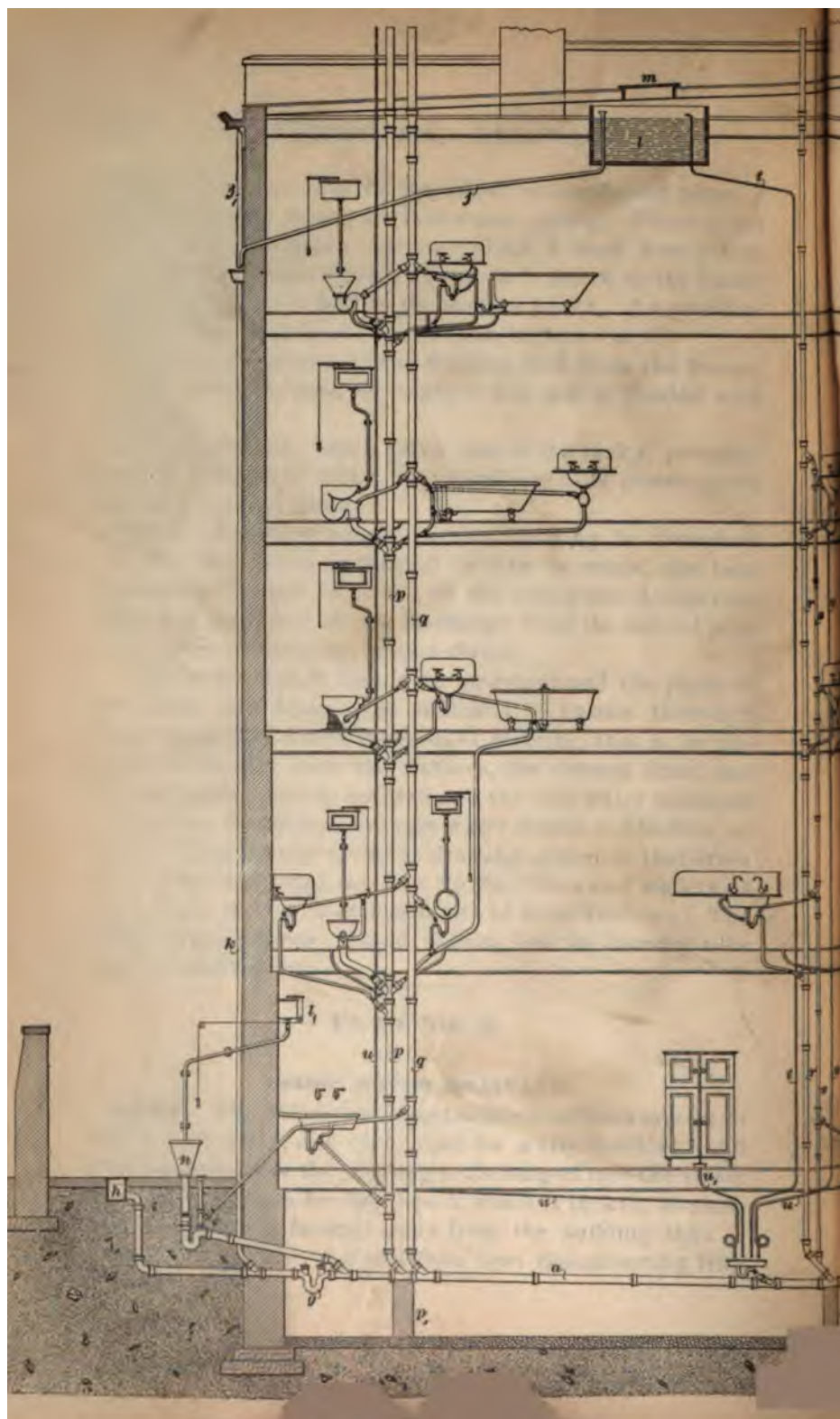
If the water supply should be abundant and the pitch of the drains and sewer pipe sufficient to ensure thorough cleansing with ordinary methods of flushing, that is, by the simple discharge from the fixtures, the cistern, filter, and flushing tank would be omitted and the roof water would all deliver into the drains, the rain-water drains and leaders, of course, being trapped from the drainage system so that drain air or sewer gas could not flow up the rain-water leaders or conductors, and be discharged into or near windows. The grease trap, however, should remain, but the laundry tubs need not deliver into it.

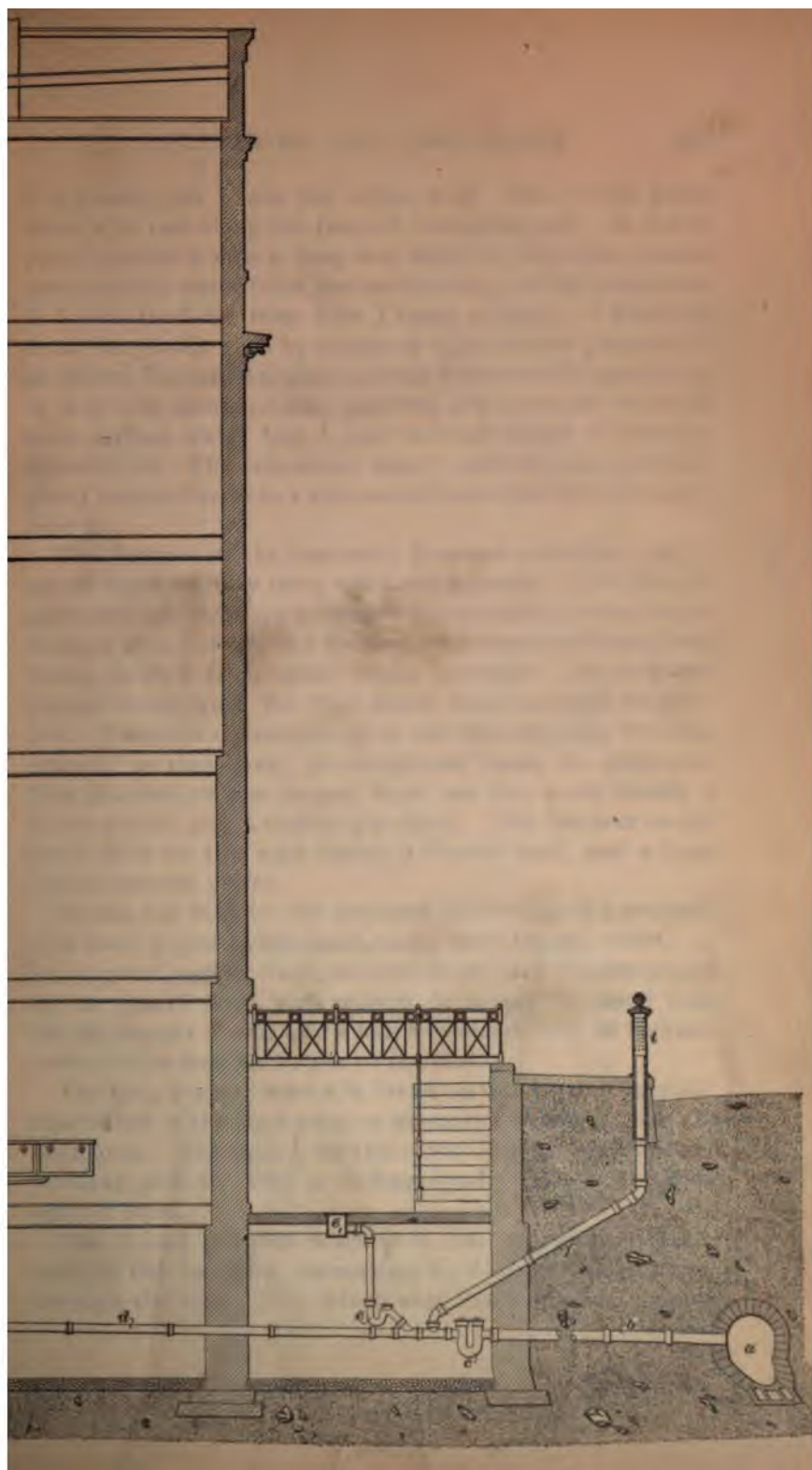
PLAN NO. 2.

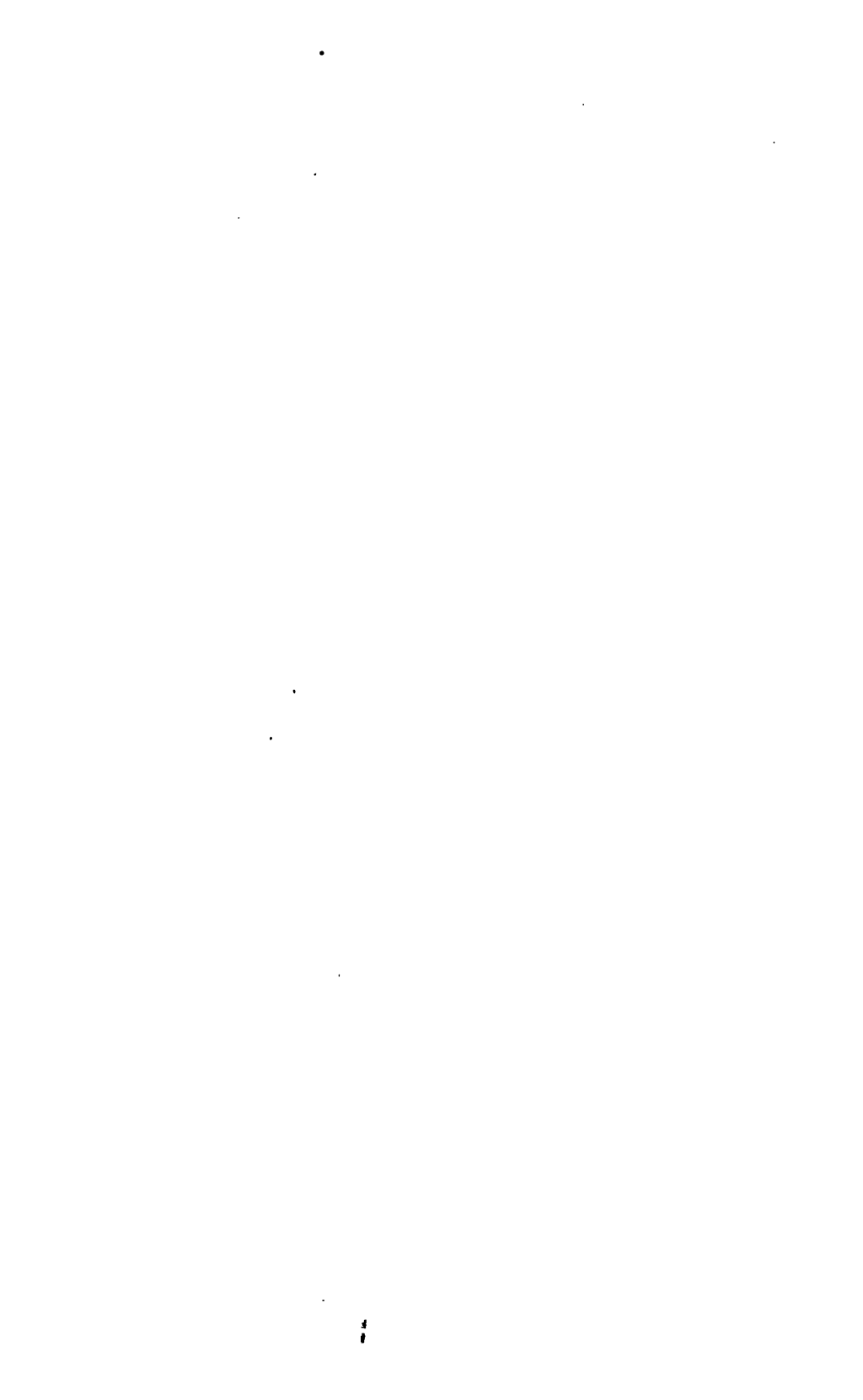
INSIDE HOUSE DRAINAGE.

1041. Fig. 365 shows in sectional elevation a system of drains, soil, waste, and vent pipes for a city building. All of the sewage from the building is discharged into the street sewer *a* by a 6-inch fireclay pipe *b*, which is broken, to show that the sewer is further away from the building than it appears in the cut. A 5 or 6-inch iron disconnecting trap









c is placed just inside the cellar wall. The 5-inch house drain *d* is run along the face of the cellar wall. A 4-inch pipe, furnished with a deep seal trap *e* in the cellar, carries away surface water from the catch basin *c*, in the front area. A 5-inch fresh-air inlet pipe *f* takes a supply of fresh air from the street curb by means of a perforated post inlet *i*, as shown, instead of a plain grating flush with the pavement. A 4-inch in diameter deep seal trap *g* disconnects the back area surface water box *h* and the roof leader *k* from the house drain. The rain-water pipe *j*₁ and the tank overflow pipe *j* both deliver into a rain-water head upon the rain-water pipe *k*.

The fixtures in the basement floor are a kitchen sink, a set of three laundry tubs, and a refrigerator. The fixtures upon the first floor are a butler's pantry sink, a corner wash basin, a water-closet, and a urinal, the closet and urinal both being flushed from small tanks overhead. In ordinary private house work the three latter fixtures would be omitted. They are connected up in the drawing only for illustration, as they may, in exceptional cases, be employed. The fixtures on the second floor are two wash basins, a Roman bath, and a siphon jet closet. The fixtures on the third floor are two wash basins, a French bath, and a front outlet washout closet.

On the top floor for the servants' use is located a common iron bath, a plain wash basin, and a short hopper closet. A rectangular, copper-lined, wooden house tank *l* is also placed on the fourth floor, high enough to supply the small tank for the hopper closet, and a hatch *m* about 20 × 30 inches is made on the roof for access to the tank.

The long hopper closet *n* is fitted up in a small "lean-to" apartment in the back area, or basement, and opens into the back area. The tank *l*₁ for this closet is fitted up inside the building, and the trap is underground. This is to guard against frost.

The 4-inch soil-pipe stack *p* is run up full size to the roof of the building, increasing to 5 inches as it passes through the roof. The 4-inch vent stack *q*, corresponding

to *p*, also increases in diameter as it passes through the roof; its base joins the house drain at an angle of 45° , so that any rust falling down may slide into *d* and thus be washed away.

The 3-inch waste-pipe stack *r* is carried full size up to the roof, and increased to 4 inches as it passes through it. For purpose of economy only, the corresponding 2-inch vent pipe *s* joins *r* above the highest fixture, instead of passing separately up to and through the roof.

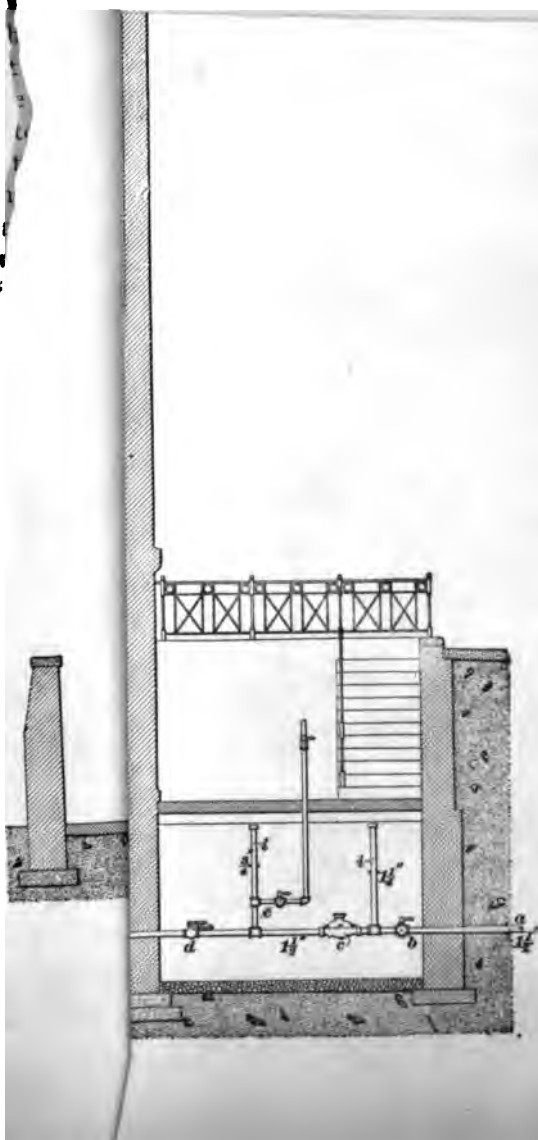
Brick piers *p*, are built under the vertical stacks to support them. The $\frac{1}{2}$ -inch telltale pipe *t*, $1\frac{1}{4}$ -inch safe wastes *u*, and refrigerator waste *u*, discharge openly into a sink in the cellar. The safe wastes are trapped by making a coil on the end of the pipe as shown, and are carried full size up to and through the roof to prevent odors from entering any of the upper rooms through them. The vent outlets above the roof should be carried up a few feet higher than shown; they are shortened in order to avoid making the drawing too large. The waste pipe from the Roman bath on second floor is dropped down and made to flush the urinal waste; but it may join the stack *p* if desired.

PLAN NO. 3.

WATER SUPPLY, STREET PRESSURE.

1042. Fig. 366 represents the building and fixtures already shown in Plan No. 2, along with a system of piping for the supply and distribution of hot and cold water, the supply being taken from the city mains. The minimum pressure in the mains must be more than that required to just raise water to the highest fixtures. With this system of piping, when the street mains are shut off, the entire building will immediately be without water, the boiler, of course, remaining full, if unsiphoned. The street-service pipe *a*, which joins the city main to the pipes in the building, has a stop and waste cock *b* attached on its end just inside the cellar. A water meter *c* fitted with an air chamber near its inlet indicates the quantity of water used in the

PLUMBING AND DRAINAGE.



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building. The pressure in the street mains in this particular case is supposed to be too great for safety or comfort, if applied to the plumbing in the building; consequently, a pressure-reducing valve *d* is placed on the house-service pipe just inside the pipe *e* which supplies a hose bibb in the front area with water under the full pressure of the main. The stop and waste cock shown on this pipe is to shut off and drain the area pipe during cold weather.

Let us suppose that the average main pressure is 95 lb. by the gauge, and that we reduce this pressure, by the use of *d*, to a constant pressure of 45 lb. within the building; then the size of the pipes may be approximately as marked on the drawing. The hot and cold distributing pipes are galvanized iron or brass, and some of the branches are shown of lead.

Since the pressure-reducing valve is similar to a check-valve, a safety valve is placed upon the boiler, and a pipe *g* leads any blow-off from *f* into the kitchen sink. A few lever-handle stop and waste cocks are placed upon the most important parts of the system to facilitate shutting off sections, for repairs, etc., without shutting off the entire building. Each closet tank may be shut off separately, because the ball-cocks or the tank valves in them generally require repairs more frequently than other parts of the system. The boiler and the water-back *h* furnish hot water for the entire building. It will be observed in this drawing that there is no circulation of hot water between the boiler and the fixtures, and that a considerable quantity of cold water must be drawn from some of the fixtures before the hot water flows. Air chambers *i*, *i*, etc., are attached to the piping to prevent water hammer.

The sediment pipe *j* joins the kitchen sink trap on the house side of the seal. The piping in this sketch is exaggerated in size, and to the eye may appear out of proportion with the fixtures. This, however, was done to show the pipe connections clearly. The inside diameters of the pipes are marked on the drawing.

PLAN NO. 4.**WATER SUPPLY, TANK PRESSURE.**

1043. In this plan, Fig. 367, the same building and the same fixtures as those in Plans Nos. 2 and 3 are shown. The fixtures are all supplied from a house tank *a* on the top floor. This tank is filled with water from a rising main *b* which joins the service pipe *c* in the cellar. If the water in the main will not rise by its pressure in the service pipe to the tank, it must be forced. This can be done by attaching a lift and force pump either to *b* or *c*.

The system shown is well adapted to cases where the water supply is intermittent, such, for example, as in towns or cities where water pressure at best is low, and where factories, mills, and other works lessen the pressure during the day to such an extent that the water can not run to the upper floors of the building.

If the water should rise high enough at night to flow into the tank, it may do so if the ball-cock *k* is open. The tank should be large enough to hold at least a two-days' supply.

Two cold-water distributing lines *d*, *d*₁ supply cold water to the fixtures. The one to the left feeds the boiler. Stop cocks *e* and *f* placed on these pipes just under the tank shut the water off the building. Circulation pipes *g*, *g*₁ run from the upper ends of the hot-water distributing pipes *l* and *l*₁ to the boiler *m* to ensure a supply of hot water at the upper fixtures the moment the faucets are opened.

The hot water pipes shown are made of iron or brass and the cold water pipes of lead, except those from the main, which are iron. The pipe *h* furnishes fresh water from the main for cooking and drinking purposes. Relief pipes *i*, *i*₁, taken from the tops of the hot water pipes, are turned over the top of the tank. To prevent a water hammer in *c* from affecting the ball-cock in the tank or in the meter *n*, a special air chamber is attached to the main at *j*. To secure a good flow of water throughout the building, the pipes may be of the sizes given, which are the nominal internal diameters.

In this system, the boiler may be smaller than in Plan No. 3, or a larger water-back may be used, because considerable heat is transmitted from the hot water while it circulates through the building. A row of lever-handle stop cocks is arranged over the boiler for convenience in shutting off the water.

The piping and connections in this plan are also exaggerated in size.

PLAN NO. 5.

WATER SUPPLY, DOUBLE-BOILER SYSTEM.

1044. Fig. 368 shows how the lower floors of a building may be supplied with hot and cold water from the city mains, while the upper floors are supplied from a tank, one water-back being employed to heat the water for the entire building.

The dotted line *AB* shows the height to which the street water will rise; therefore, the fixtures above that are supplied from the tank *a*. Of course, those below *AB* may also be supplied from *a*, but to economize pumping, the piping is so arranged that they can be supplied direct from the street.

An Ericsson hot-air pumping engine *r* is shown in the cellar, having its suction pipe *b* connected to the main *c*, and its delivery pipe *s* leading over and into the tank *a*. The engine is supplied with a gas-burner, and can be stopped when the tank is full by the arrangement shown at the wheel valve *d* over the basement sink. A water-line indicator *e* is placed over the kitchen sink so that the servants may see how much water is in the tank. This sliding indicator is attached to a float in the tank by a chain or wire, working over two pulleys. When the tank is empty, the float falls with the water and raises the indicator to the top of the slide board, and when filled again the indicator falls towards the bottom. The slide board is graduated in feet and inches, and if the indicator is regulated properly it

will indicate the depth of water in the tank very accurately. This plate also shows hot-water circulation to all the fixtures, except the kitchen sink and laundry tubs, the branches to which are short. Circulation to these fixtures may be obtained by dropping the return pipe below the boiler level, and connecting the branches to the returns. If such connections are made, however, there will be danger of hot water being drawn from the bottom of the boiler along with hot water from the flow pipes, unless check-valves are used on the returns near the boiler. Some plumbers object to check-valves on returns, and, consequently, connect these fixtures as shown.

The check-valve *f* will admit water to flow from the outer boiler or street main to the inner boiler, when the pressure in the inner boiler is less than that in the outer one, but will prevent any water in the inner boiler from passing out again.

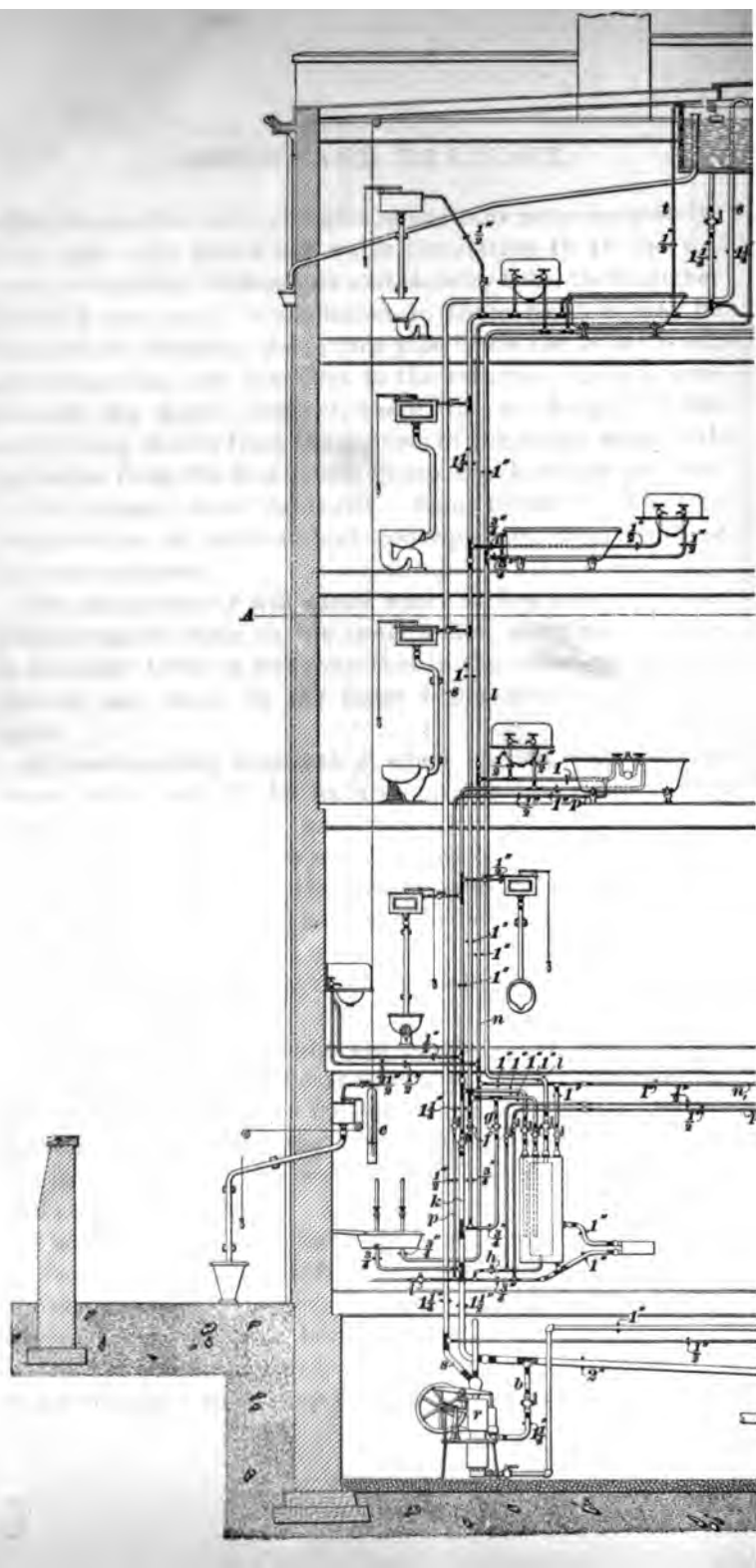
A lever-handled stop-cock *g*, when opened, will feed the outer boiler and all the fixtures on the lower floors with tank water. Of course, when this cock is opened the valve on the street-service pipe must be closed, otherwise the tank water will flow back to the street mains. If the cock *g* be used much, a swinging check should be placed on the main service pipe *c*.

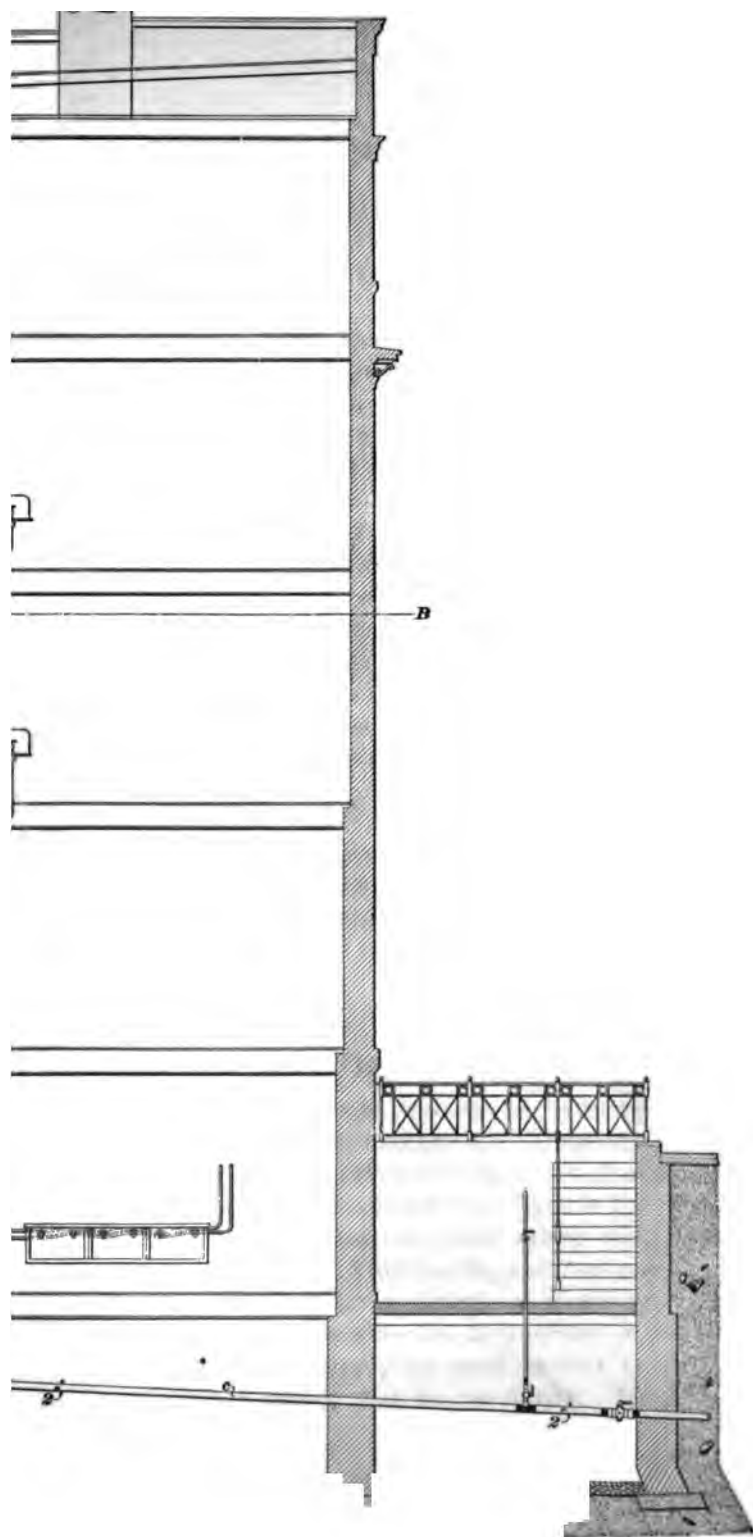
The sediment cock for the inner boiler is shown at *h*, and for the outer boiler at *i*.

The water-back is connected to the outer boiler in the ordinary manner, and heats water for the entire building. The telltale *j* flows into the pan of the automatic shut-off valve *d*, so that when the tank is full, the telltale will fill the pan with water, the weight of which will close the valve and stop the engine.

The rising main supplies cold water to the outer boiler, kitchen sink, and fixtures on first and second floors above, except the water-closet on second floor, which is supplied from the tank, because it is too near *A B*.

The hot supply to third and fourth floors, or **tank hot**, flows through *l* to the top floor, where an expansion pipe is





taken off its highest point and led over the tank. This pipe then continues and drops to supply the wash basin to the right on the third floor. It is then continued back to the boiler by the return pipe *m*. The hot supply to basement and first and second floors, flows through *n* and *n*₁, the end of *n* being run up to and over the tank as an expansion pipe and air vent. The pipes *p*, *p*₁ are for the circulation of the street hot supply. If desired, a small pipe may be run from the hot supply branch *q* to over the tank to carry off any air that might accumulate there and stop circulation.

The pipe *t* acts only as a relief pipe, and may or may not be used.

In this drawing, it is assumed that the street water will not at any time be sufficient to rise into the tank; otherwise, the expansion and relief pipes would be omitted, or carried considerably above the tank, to prevent the temporarily increased main pressure from forcing hot water into the tank.

The student should carefully study the different lines of pipes in the five preceding figures, until he thoroughly understands the duty of each pipe, and thoroughly grasps the principles of supply and distribution of hot and cold water, and the proper construction of soil, waste, vent, and drain-pipe lines.

LAWS AND REGULATIONS.

1045. The plumbing and drainage of buildings is regulated by law in many cities and towns. These regulations establish a standard of general excellence, to which all plumbers must conform. The standard thus fixed is the lowest that will be tolerated, or that the public safety will permit. It is not the highest standard attainable, and does not aim to secure the *best* possible arrangement of drainage. The plumber should carefully consider the arrangements in every case, and should aim to supply the most perfect system of drainage and water supply that he can devise. He should

not limit himself to the specific requirements of the law, but should do as much better as possible.

The following verbatim copy of the regulations which are now in force in the city of New York, should be carefully studied, and attention should also be given to the regulations in force in your own town or city:

Health Department,

CITY OF NEW YORK.

The Registration of Plumbers, and the Law and Regulations Governing the Plumbing and Drainage of all Buildings Hereafter Erected.

CHAPTER 450, LAWS OF 1881.

AN ACT to secure the Registration of Plumbers and the Supervision of Plumbing and Drainage in the Cities of New York and Brooklyn.

Passed June 4, 1881.

The People of the State of New York, represented in Senate and Assembly, do enact as follows:

SECTION 1. On or before the first day of March, eighteen hundred and eighty-two, every master or journeyman plumber carrying on his trade in the cities of New York and Brooklyn, shall, under such rules and regulations as the respective Boards of Health of the Health Departments of the said cities shall respectively prescribe, register his name and address at the Health Department of the said city; and after the said date it shall not be lawful for any person to carry on the trade of plumbing in the said cities unless his name and address be registered as above provided.

SEC. 2. A list of the registered plumbers of the city of New York shall be published in the City Record at least once in each year.

SEC. 3. The drainage and plumbing of all buildings, both public and private, hereafter erected in the city of New

York, or in the city of Brooklyn, shall be executed in accordance with plans previously approved in writing by the Board of Health of the said Health Departments of said cities, respectively. Suitable drawings and descriptions of the said plumbing and drainage shall in each case be submitted and placed on file in the Health Department. The said Boards of Health are also authorized to receive and place on file drawings and descriptions of the plumbing and drainage of buildings erected prior to the passage of this act in their respective cities.

SEC. 4. The Board of Estimate and Apportionment of the city of New York shall add six thousand dollars to the apportionment of the Health Department for the year eighteen hundred and eighty-one, and shall insert the same in the tax levy, to provide for carrying out the provisions of this act, so far as it relates to the city of New York.

SEC. 5. Any court of record in said cities, respectively, or any judge or justice thereof, shall have power at any time after the service of notice of the violation of any of the provisions of this act, and upon the affidavit of one of the Commissioners of Health of the said cities, to restrain by injunction order, the further progress of any violation named in this act, or of any work upon or about the building or premises upon which the said violation exists; and no undertaking shall be required as a condition to the granting or issuing of such injunction, or by reason thereof.

SEC. 6. Any person violating any of the provisions of this act shall be deemed guilty of a misdemeanor.

SEC. 7. This act shall take effect immediately.

RULES AND REGULATIONS.

1046. Drawings and triplicate descriptions on forms furnished by the Department of Buildings for all plumbing and drainage shall be filled in with ink and filed by the owner, architect, or plumber in the said Department.

And the said plumbing and drainage shall not be

commenced or proceeded with until said drawings and descriptions shall have been so filed and approved by the Superintendent of Buildings.

No modification of the approved drawings and descriptions will be permitted unless either amended drawings and triplicate descriptions, or an amendment to the original drawings and descriptions, covering the proposed change or changes, are so filed and approved by the Superintendent of Buildings.

It shall not be lawful to do said plumbing and drainage except pursuant to said approved drawings and descriptions or approved amendments thereof.

Repairs or alterations of plumbing and drainage may be made without the filing and approval of drawings and descriptions in the Department of Buildings. But said repairs or alterations shall not be construed to include cases where new vertical and horizontal lines of soil, waste, vent, or leader pipes are proposed to be used.

Notice of said repairs or alterations shall be given to the said Department, before the same are commenced, in all cases, except where leaks are stopped or obstructions are removed.

Said notice shall consist of a description in writing of the work to be done, of the location of the property where the same is executed, and of the names and addresses of the owner and of the plumber.

Said notice shall not, however, be required when repairs or alterations are ordered by the Board of Health for sanitary reasons.

Said repairs and alterations shall comply in all respects with the weight, quality, arrangement, and venting of the rest of the work in the building.

The plans must be drawn to scale in ink on cloth, or they must be cloth prints of such scale drawings, and shall consist of such floor plans and sections as may be necessary to show clearly all plumbing work to be done, and must show partitions and the method of ventilating water-closet apartments.

Written notice must be given to the Department of Buildings by the plumber when any work is begun, and from time to time when any work is ready for inspection. No part of the work shall be covered until it has been examined, tested, and approved by the Inspector.

1047. Definition of Terms.—The term "private sewer" is applied to main sewers that are not constructed by and under the supervision of the Department of Public Works or the Department of Street Improvements of the Twenty-third and Twenty-fourth Wards.

The term "house sewer" is applied to that part of the main drain or sewer extending from a point two feet outside of the outer face of the outer front vault or area wall to its connection with the public sewer, private sewer, or cesspool.

The term "house drain" is applied to that part of the main horizontal drain and its branches inside the walls of the building and extending to and connecting with the house sewer.

The term "soil pipe" is applied to any vertical line of pipe, extending through roof, receiving the discharge of one or more water-closets, with or without other fixtures.

The term "waste pipe" is applied to any pipe extending through roof, receiving the discharge from any fixtures except water-closets.

The term "vent pipe" is applied to any special pipe provided to ventilate the system of piping and to prevent trap siphonage and back pressure.

1048. I. Materials and workmanship.—All materials must be of the best quality, free from defects, and all work must be executed in a thorough workmanlike manner.

All cast-iron pipes and fittings must be uncoated, sound, cylindrical, and smooth, free from cracks, sand holes, and other defects, and of uniform thickness and of the grade known in commerce as extra heavy.

Pipe, including the hub, shall weigh not less than the following average weights per lineal foot:

Diameters.	Weights per Lineal Foot.
2 inches	5½ pounds.
3 inches	9½ pounds.
4 inches	13 pounds.
5 inches	17 pounds.
6 inches	20 pounds.
7 inches	27 pounds.
8 inches	33½ pounds.
10 inches	45 pounds.
12 inches	54 pounds.

The size, weight, and maker's name must be cast on each length of the pipe.

All joints must be made with picked oakum and molten lead and be made gas-tight. Twelve (12) ounces of fine, soft pig lead must be used at each joint for each inch in the diameter of the pipe.

All wrought-iron and steel pipe must be equal in quality to "Standard," and be properly tested by the manufacturer. All pipe must be lap-welded. No plain black or uncoated pipe will be permitted.

After January 1, 1897, wrought-iron and steel pipe must be galvanized, and each length must have the weight per foot and maker's name stamped on it.

Fittings for vent pipes on wrought-iron or steel pipes may be the ordinary cast or malleable steam and water fittings.

Fittings for waste or soil pipes must be the special, extra heavy cast-iron recessed and threaded drainage fittings, with smooth interior waterway and threads tapped, so as to give a uniform grade to branches of not less than ¼ of an inch per foot.

All joints to be screwed joints made up with red lead, and the burr formed in cutting must be carefully reamed out.

Short nipples on wrought-iron or steel pipe where the unthreaded part of the pipe is less than one and one-half ($1\frac{1}{2}$) inches long must be of the thickness and weight known as "extra heavy" or "extra strong."

The pipe shall be not less than the following average thickness and weight per lineal foot:

Diameters.	Thicknesses.	Weights per Lineal Foot.
$1\frac{1}{2}$ inches	.14 inches.	2.68 pounds.
2 inches	.15 inches.	3.61 pounds.
$2\frac{1}{2}$ inches	.20 inches.	5.74 pounds.
3 inches	.21 inches.	7.54 pounds.
$3\frac{1}{2}$ inches	.22 inches.	9.00 pounds.
4 inches	.23 inches.	10.66 pounds.
$4\frac{1}{2}$ inches	.24 inches.	12.34 pounds.
5 inches	.25 inches.	14.50 pounds.
6 inches	.28 inches.	18.76 pounds.
7 inches	.30 inches.	23.27 pounds.
8 inches	.32 inches.	28.18 pounds.
9 inches	.34 inches.	33.70 pounds.
10 inches	.36 inches.	40.06 pounds.
11 inches	.37 inches.	45.02 pounds.
12 inches	.37 inches.	48.98 pounds.

All brass pipe for soil, waste, and vent pipes and solder nipples must be thoroughly annealed, seamless, drawn brass tubing, of standard iron-pipe gauge. Connections on brass pipe and between brass pipe and traps or iron pipe must not be made with slip joints or couplings. Threaded connections on brass pipe must be of the same size as iron-pipe threads for same size of pipe and be tapered.

The following average thickness and weights per lineal foot will be required:

Diameters.	Thicknesses.	Weights per Lineal Foot.
1½ inches	.14 inches.	2.84 pounds.
2 inches	.15 inches.	3.82 pounds.
2½ inches	.20 inches.	6.08 pounds.
3 inches	.21 inches.	7.92 pounds.
3½ inches	.22 inches.	9.54 pounds.
4 inches	.23 inches.	11.29 pounds.
4½ inches	.24 inches.	13.08 pounds.
5 inches	.25 inches.	15.37 pounds.
6 inches	.28 inches.	19.88 pounds.

Brass ferrules must be best quality, bell-shaped, extra heavy cast brass, not less than four inches long and two and one-quarter inches, three and one-half inches, and four and one-half inches in diameter, and not less than the following weights:

Diameters.	Weights.
2½ inches.	1 pound 0 ounces.
3½ inches.	1 pound 12 ounces.
4½ inches.	2 pounds 8 ounces.

One and one-half inch ferrules are not permitted. Soldering nipples must be heavy cast brass or of brass pipe, iron-pipe size. When cast, they must be not less than the following weights:

Diameters.	Weights.
1½ inches.	0 pounds 8 ounces.
2 inches.	0 pounds 14 ounces.
2½ inches.	1 pound 6 ounces.
3 inches.	2 pounds 0 ounces.
4 inches.	3 pounds 8 ounces.

Brass screw caps for cleanouts must be extra heavy, not less than one-eighth of an inch thick, and must have a flange of not less than three-sixteenths of an inch thick.

The screw cap must have a solid square or hexagonal nut not less than one (1) inch high, with a least diameter of one and one-half ($1\frac{1}{2}$) inches. The body of the cleanout ferrule must at least equal in weight and thickness the calking ferrule for the same size of pipe. Where cleanouts are required by rules and by the approved plans, the screw cap must be of brass. The engaging parts must have not less than six (6) threads of iron-pipe size and tapered. Cleanouts must be of full size of the trap up to four (4) inches in diameter and not less than four (4) inches for large traps.

The use of lead pipe is restricted to the short branches of the soil, waste, and vent pipes, bends, and traps, roof connection of inside leaders, and flush pipes.

All lead, waste, soil, vent, and flush pipes must be of the best quality drawn pipe of the quality known in commerce as "D," and of not less than the following weights per lineal foot:

Diameters.	Weights per Lineal Foot.
$1\frac{1}{4}$ inches (for flush pipes only)	$2\frac{1}{2}$ pounds.
$1\frac{1}{2}$ inches	3 pounds.
2 inches	4 pounds.
3 inches	6 pounds.
4 and $4\frac{1}{2}$ inches	8 pounds.

All lead traps and bends must be of the same weights and thicknesses as their corresponding pipe branches. Sheet lead for roof flashings must be six-pound lead, and must extend not less than six (6) inches from the pipe and the joint made water-tight. Copper tubing when used for inside leader roof connections must be seamless drawn tubing, not

less than 22 gauge, and when used for roof flashings, must be not less than 18 gauge.

1049. II. General plan of plumbing and drainage approved by the Superintendent of Buildings.—Each building must be separately and independently connected with the public or a private sewer.

The entire plumbing and drainage system of every building must be entirely separate and independent of that of any other building.

Every building must have its sewer connections directly in front of the building, unless permission is otherwise granted by the Superintendent of Buildings.

Where there is no sewer in the street or avenue, and it is possible to construct a private sewer to connect with a sewer in an adjacent street or avenue, a private sewer must be constructed.

It must be laid outside the curb, under the roadway of the street.

Cesspools and privy vaults will be permitted only after it has been shown to the satisfaction of the Superintendent of Buildings that their use is absolutely necessary.

When allowed, they must be constructed strictly in accordance with the terms of the permit issued by the Superintendent of Buildings.

Cesspools will not be permitted under any circumstances for tenement and lodging houses. Cesspools will not be allowed outside the frame building district. As soon as it is possible to connect with a public sewer, the owner must have the cesspool and privy vault emptied, cleaned, and disinfected, and filled with fresh earth, and have a sewer connection made in the manner herein prescribed.

Old house sewers can be used in connection with the new buildings or new plumbing only when they are found on examination by the Plumbing Inspector to conform in all respects to the requirements governing new sewers.

When a proper foundation, consisting of a natural bed of earth, rock, etc., can be obtained, the house sewer can be of earthenware pipe.

Where the ground is made or filled in, or where the pipes are less than three feet deep, or in any case where there is danger of settlement by frost or from any other cause, and when cesspools are used, the house sewer must be of extra heavy cast-iron pipe with lead-calked joints.

The house sewer and house drain must be at least 4 inches in diameter where water-closets discharge into them.

Where rain water discharges into them, the house sewer and the house drain up to the leader connections must be in accordance with the following table:

Diameter.	Fall $\frac{1}{2}$ inch per Foot.	Fall $\frac{1}{2}$ inch per Foot.
6 inches . .	5,000 sq. ft.	7,500 sq. ft. of drainage of area.
7 inches . .	6,900 sq. ft.	10,300 sq. ft. of drainage of area.
8 inches . .	9,100 sq. ft.	13,600 sq. ft. of drainage of area.
9 inches . .	11,600 sq. ft.	17,400 sq. ft. of drainage of area.

No steam exhaust, boiler blow-off, or drip pipe shall be connected with the house drain or sewer. Such pipes must first discharge into a proper condensing tank, and from this a proper outlet to the house sewer outside the building must be provided. In low-pressure steam systems the condensing tank may be omitted, but the waste connection must be otherwise, as above required.

The house drain and its branches must be of extra heavy cast iron when under ground, and of extra heavy cast iron, or galvanized, tarred, or asphalted wrought iron or steel when above ground.

The house drain must properly connect with the house sewer at a point two feet outside of the outer front vault or area wall of the building. An arched or other proper opening must be provided for the drain in the wall to prevent damage by settlement.

The house drain and sewer must be run as direct as possible, with a fall of at least one-quarter inch per foot, all

changes in direction made with proper fittings, and all connections made with Y branches and one-eighth and one-sixteenth bends.

If possible, the house drain must be above the cellar floor. The house drain must be supported at intervals of 19 feet by 8-inch brick piers, or suspended from the floor-beams, or be otherwise properly supported by heavy iron pipe hangers at intervals of not more than 10 feet.

The use of pipe hooks for supporting drains is prohibited.

An iron running trap must be placed on the house drain near the wall of the house, and on the sewer side of all connections, except a drip pipe where one is used. If placed outside the house or below the cellar floor, it must be made accessible in a brick manhole, the walls of which must be 8 inches thick, with an iron or flagstone cover. When outside the house it must never be less than 3 feet below the surface of the ground. The house trap must have two cleanouts with brass screw cap ferrules calked in.

A fresh-air inlet must be connected with the house drain just inside of the house trap. The fresh-air inlet will be of extra heavy cast iron where under ground. Where possible it will extend to the outer air and finish with a return bend at least one foot above grade, and 15 feet away from any window or furnace cold-air box. When this arrangement is not possible, the fresh-air inlet must open into the side of a box not less than 18 inches square, placed below the sidewalk, at the curb. The bottom of the box must be 18 inches below the under side of the fresh-air inlet pipe. The box may be of cast iron, or it may be constructed with 8-inch walls of brick or flagstone laid in hydraulic cement. The box must be covered by a flagstone fitted with removable metal grating, leaded into the stone, having openings equal in area to the area of the fresh-air inlet, and not less than one-half inch in their least dimension. The fresh-air inlet must be of the same size as the drain up to four (4) inches; for five (5) inch and six (6) inch drains it must be not less than four (4) inches in diameter; for seven (7) inch and eight (8) inch drains, not less than six (6) inches in

diameter, and for larger drains not less than eight (8) inches in diameter.

All yards, courts, and areas must be drained. Tenement houses and lodging houses must have their yards, areas, and courts drained into the sewer.

These drains when sewer-connected must have connections not less than three inches in diameter. They should if possible be controlled by one trap—the leader trap if possible. Leader pipes must be sewer-connected if possible.

All buildings shall be kept provided with proper metallic leaders for conducting water from the roofs in such manner as shall protect the walls and foundations of said buildings from injury. In no case shall the water from said leaders be allowed to flow upon the sidewalk, but the same shall be conducted by pipe or pipes to the sewer. If there be no sewer in the street upon which such buildings front, then the water from said leader shall be conducted by proper pipe or pipes, below the surface of the sidewalk, to the street gutter.

Inside leaders must be made of cast iron, wrought iron, or steel, with roof connections made gas and water-tight by means of a heavy lead or copper drawn tubing wiped or soldered to a brass ferrule, or nipple-calked or screwed into the pipe.

Outside leaders may be of sheet metal, but they must connect with the house drain by means of a cast-iron pipe extending vertically five feet above the grade level.

Leaders must be trapped with cast-iron running traps, so placed as to prevent freezing. Rain-water leaders must not be used as soil, waste, or vent pipes, nor shall any such pipe be used as a leader.

Cellar drains will be permitted only where they can be connected to a trap with a permanent water seal.

Subsoil drains should discharge into a sump or receiving tank, the contents of which must be lifted and discharged into the drainage system above the cellar bottom by some approved method.

Where directly sewer-connected they must be cut off from

the rest of the plumbing system by a brass flap valve on the inlet to the catch basin, and the trap on the drain from the catch basin must be water supplied as required for cellar drains.

Foundation walls must, where required, be rendered impervious to dampness by the use of coal tar, pitch, or asphaltum.

Full size Y and T branch fittings for handhole cleanouts must be provided where required on house drain and its branches.

All iron traps for house drain, yard, and other drains and leaders must be running traps with handhole cleanouts of full size of the traps when same are less than five (5) inches. All traps under ground must be made accessible by brick manholes with proper covers.

SOIL AND WASTE PIPE LINES.

1050. All main soil, waste, or vent pipes must be of iron, steel, or brass. When they receive the discharge of fixtures on any floor above the first, they must be extended in full caliber at least one foot above the roof coping, and well away from all shafts, windows, chimneys, or other ventilating openings. When less than four inches in diameter, they must be enlarged to four inches at a point not less than one foot below the roof surface by an increasor not less than nine (9) inches long.

No caps, cowl, or bends shall be affixed to the top of such pipe.

In tenement-houses and lodging-houses wire baskets must be securely fastened into the opening of each pipe that is in an accessible position.

All pipes issuing from extensions or elsewhere, which would otherwise open within 30 feet of the window of any building, must be extended above the highest roof and well away from and above all windows.

The arrangement of all pipe lines must be as straight and direct as possible. Offsets will be permitted only when unavoidable.

Necessary offsets above the highest fixture branch must not be made at an angle of less than 45 degrees to the horizontal.

All pipe lines must be supported at the base on brick piers or by heavy iron hangers from the cellar ceiling beams and along the line by heavy iron hangers at intervals of not more than ten feet.

All pipes and traps should, where possible, be exposed to view. They should always be readily accessible for inspection and repairing.

No trap shall be placed at the foot of main soil and waste pipe lines.

The sizes of soil and waste pipes must be not less than those given in the following table :

Main soil pipe, 4 inches in diameter; main waste pipe, 2 inches in diameter; branch soil pipe, 4 inches in diameter; branch waste for laundry tubs, 2 inches in diameter; branch waste for kitchen sink, 2 inches in diameter; soil pipe for water-closets on five or more floors, 5 inches in diameter; waste pipes for kitchen sinks on five or more floors, 3 inches in diameter; main soil pipe for three-family tenement-houses exceeding three stories, 4 inches in diameter.

In every building where there is a leader connected to the drain, if there are any plumbing fixtures, there must be at least one four (4) inch pipe extending above the roof for ventilation.

Soil and waste pipes must have proper Y branches for all fixture connections.

Branch soil and waste pipe must have a fall of at least one-quarter inch per foot. Short T Y branches will be permitted on vertical lines only. Long one-quarter bends and long T Y's are permitted. Short one-quarter bends and double hubs, short roof increasors, and common offsets are prohibited.

All traps must be protected from siphonage and back pressure, and the drainage system ventilated by special lines of vent pipes.

All vent pipe lines and main branches must be of iron,

steel, or brass. They must be increased in diameter and extended above the roof as required for waste pipes. They may be connected with the adjoining soil or waste line well above the highest fixture, but this will not be permitted when there are fixtures on more than six floors.

All offsets must be made at an angle of not less than forty-five degrees to the horizontal, and all lines must be connected at the bottom with a soil or waste pipe or the drain in such a manner as to prevent the accumulation of rust scale.

Branch vent pipes should be kept above the top of all connecting fixtures, to prevent the use of vent pipes as soil or waste pipes. They will not be permitted lower than the outlet of the highest fixture in the group. Branch vent pipes should be connected as near to the crown of the trap as possible.

The sizes of vent pipes throughout must not be less than the following :

For main vents and long branches, two inches in diameter; for water-closets on three or more floors, three inches in diameter; for other fixtures on less than seven floors, two inches in diameter; three-inch vent pipe will be permitted for less than nine stories; for more than eight and less than sixteen stories, four inches in diameter; for more than fifteen and less than twenty-two stories, five inches in diameter; for more than twenty-one stories, six inches in diameter; branch vents for traps larger than two inches, two inches in diameter; traps two inches or less, one and one-half inches in diameter.

For fixtures other than water-closets and slop sinks and for more than eight (8) stories, vent pipes may be one (1) inch smaller than above stated.

No sheet metal, brick, or other flue shall be used as a vent pipe.

Earthenware traps for water-closets and slop sinks must be ventilated from the branch soil or waste pipe just below the trap, and this branch vent pipe must be so connected as to prevent obstruction, and no waste pipe connected between it and the fixture. Earthenware traps must have no vent horns.

Every fixture must be separately trapped by a water-sealing trap placed as close to the fixture outlet as possible.

A set of wash trays may connect with a single trap, or into the trap of an adjoining sink, provided both sink and tub waste outlets are on the same side of the waste line, and the sink is nearest the line. When so connected, the waste pipe from the wash trays must be branched in below the water seal.

The discharge from any fixture must not pass through more than one trap before reaching the house drain.

All traps must be well supported and set true with respect to their water levels.

All traps must have a water seal of at least one and one-half inches.

No masons, cesspool, bell, pot, bottle, or **D** trap will be permitted, nor any form of trap that is not self-cleaning, nor that has interior chamber or mechanism, nor any trap, except earthenware ones that depend upon interior partitions for a seal.

All fixtures, other than water-closet and urinals, must have strong metallic strainers or bars over the outlets to prevent obstruction of the waste pipe.

All exposed or accessible traps, except water-closet traps, must have brass trap screws for cleaning the trap, placed on the inlet side, or below the water level.

Traps for water-closets must not be less than four inches in diameter; traps for slop sinks must not be less than two inches in diameter; traps for kitchen sinks must not be less than two inches in diameter; traps for wash trays must not be less than two inches in diameter; traps for urinals must not be less than two inches in diameter; traps for other fixtures must not be less than one and one-half inches in diameter.

Overflow pipes from fixtures must in all cases be connected on the inlet side of traps.

All earthenware traps must have heavy brass floor plates soldered to the lead bends and bolted to the trap flange, and

the joint made gas-tight with red or white lead. The use of rubber washers for floor connections is prohibited.

Earthenware water-closets must be set on marble or slate in all new work, and when it is not impossible to use it because of water pipes or other obstructions in all alterations, old work.

Safe and refrigerator waste pipes must be of galvanized iron, and be not less than one (1) inch in diameter, with lead branches of the same size with strainers over the inlet secured by a bar soldered to the lead branch.

Safe waste pipes must not connect directly with any part of the plumbing system.

Safe waste pipes must either discharge over an open, water-supplied, publicly placed, ordinarily used sink, placed not more than three and one-half feet above the cellar floor, or they may discharge upon the cellar floor.

The safe waste pipe from a refrigerator can not discharge upon the ground or floor. It must discharge over an ordinary portable plan, or over some properly trapped water-supplied sink, as above.

The branches on vertical lines must be made by Y fittings, and be carried up to the safe with as much pitch as possible.

Lead safes must be graded and neatly turned over bevel strips at their edges.

Where there is an offset on a refrigerator waste pipe in the cellar, there must be cleanouts to control the horizontal part of the pipe.

In tenement-houses and lodging-houses the refrigerator waste pipes must extend above the roof and must not be larger than one and one-half inches, nor the branches smaller than one and one-quarter inches. These branches must have full size accessible traps.

Refrigerator waste pipes, except in tenement-houses, and all safe waste pipes must have brass flap valves at their lower ends.

1051. Fixtures.—In tenement-houses, lodging-houses, factories, and workshops the water closets must be set on

marble, slate, or tile, and the back and ends of the water-closet apartment must be made water-proof with some similar non-absorbent material.

The closets must be set open and free from all inclosing woodwork.

Where water-closets will not support a rim seat, the seat must be supported on galvanized-iron legs, and a drip tray must be used.

The general water-closet accommodations for a tenement or lodging house can not be placed in the cellar, and no water-closet can be placed outside of the building.

In tenement-houses and lodging-houses there must be one water-closet on each floor, and when there is more than one family on a floor there will be one additional water-closet for every two additional families.

In lodging-houses where there are more than 15 persons on any floor there must be an additional water-closet on that floor for every 15 additional persons or fraction thereof.

In all other sewer-connected occupied buildings there must be at least one water-closet, and there must be additional closets so that there will never be more than 15 persons per closet.

In tenement-houses and lodging-houses the water-closet and urinal apartments must have a window opening to the outer air, or to a ventilating shaft, not less than 10 square feet in area.

In all buildings the outside partition of such apartment must extend to the ceiling or be independently ceiled over, and these partitions must be air-tight, except at the bottom of the door, which must be cut away or provided with openings to promote ventilation. The outside partitions must include a window opening to outer air on the lot whereon the building is situated, or some other approved means of ventilation must be provided. When necessary to properly light such apartments, the upper part of the partitions must be made of glass. The interior partitions of such apartments must be dwarf partitions.

Pan, valve, plunger, and other water-closets having an

unventilated space, or whose walls are not thoroughly washed at each discharge, will not be permitted.

All water-closets must have earthenware flushing rim bowls. "Pipe wash" bowls or hoppers will not be permitted.

Long hoppers will not be permitted except where there is an exposure to frost.

Where water-closet or other fixture traps are of iron they must be porcelain-lined.

Drip trays must be enameled on both sides and secured in place.

Water-closets and urinals must never be connected directly with or flushed from the water-supply pipes.

Water-closets and urinals must be flushed from a separate cistern, the water from which is used for no other purpose.

The overflow of cisterns may discharge into the bowls of the closet, but in no case connect with any part of the drainage system.

Iron water-closet cisterns and automatic urinal cisterns are prohibited.

The copper lining of water-closet and urinal cisterns must be not lighter than ten (10) ounce copper.

Water-closet flush pipes must not be less than one and one-fourth inches, and urinal flush pipes one (1) inch in diameter, and if of lead must not weigh less than two and one-half pounds and two pounds per lineal foot. Flush couplings must be of full size of the pipe.

Latrines, trough water-closets, and similar appliances may be used only on written permit from the Superintendent of Buildings, and must be set and arranged as may be required by the terms of the permit.

All urinals must be constructed of materials impervious to moisture that will not corrode under the action of urine. The floor and walls of the urinal apartments must be lined with similar non-absorbent and non-corrosive material.

The platforms or treads of urinal stalls must never be connected independently to the plumbing system, nor can they be connected to any safe waste pipe.

Iron troughs or urinals must be enameled or galvanized. In tenement-houses and lodging-houses sinks must be entirely open on iron legs or brackets, without any inclosing woodwork.

Wooden washtubs are prohibited. Cement or artificial stone tubs will be permitted, provided the same be made in the following manner, to wit: The cement or artificial stone to be one part good Portland cement to not more than three parts crushed or broken granite, gneiss, or equally hard stone, broken to a size not larger than will go through a 1-inch ring, well tamped; each tub to be branded with the owner's name and with the absolute mixture stamped on said tub, samples of which shall be filed and approved by this department; each compartment of the tub shall have a separate bottom outlet with a through-and-through fitting, and overflows shall be external to the tub.

No tubs made with cinder, ashes, or Rosendale cement, or any other materials than above specified, will be allowed.

All water-closets and other plumbing fixtures must be provided with a sufficient supply of water for flushing, to keep them in a proper and cleanly condition.

When the water pressure is not sufficient to supply freely and continuously all fixtures, a house-supply tank must be provided, of sufficient size to afford an ample supply of water to all fixtures at all times. Such tanks must be supplied from the pressure or by pumps, as may be necessary; when from the pressure, ball-cocks must be provided.

If water pressure is not sufficient to fill house tank, power pumps must be provided for filling them in tenement-houses, lodging-houses, factories, and workshops.

Tanks must be covered so as to exclude dust, and must be so located as to prevent water contamination by gases and odors from plumbing fixtures.

House-supply tanks must be of wood or iron, or of wood lined with tinned and planished copper.

House tanks must be supported on iron beams.

The overflow pipe should discharge upon the roof where possible, and in such cases should be brought down to within

six (6) inches of the roof, or it must be trapped and discharged over an open and water-supplied sink not in the same room, not over $3\frac{1}{2}$ feet above the floor. In no case shall the overflow be connected with any part of the plumbing system.

Emptying pipes for such tanks must be provided and be discharged in the manner required for overflow pipes, and may be branched into overflow pipes.

No service pipes or supplying pipes should be run, and no tanks, flushing cisterns, or water-supplied fixtures should be placed where they will be exposed to frost.

Where so placed they shall be properly packed and boxed in such a manner as to prevent freezing and to the satisfaction of the Plumbing Inspector.

The entire plumbing and drainage system within the building must be tested by the plumber, in the presence of a Plumbing Inspector, under a water or air test, as directed. All pipes must remain uncovered in every part until they have successfully passed the test. The plumber must securely close all openings, as directed by the Inspector of Plumbing. The use of wooden plugs for this purpose is prohibited.

The water test will be applied by closing the lower end of the main house drain and filling the pipes to the highest opening above the roof with water. If the drain or any part of the system is to be tested separately, there must be a head of water at least six (6) feet above all parts of the work so tested, and special provision must be made for including all joints and connections in at least one test.

The air test will be applied with a force pump and mercury column under ten pounds pressure, equal to 20 inches of mercury. The use of spring gauges is prohibited.

After the completion of the work, when the water has been turned on and the traps filled, the plumber must make a peppermint or smoke test in the presence of a Plumbing Inspector and as directed by him.

The material and labor for the tests must be furnished by the plumber. Where the peppermint test is used two ounces

of oil of peppermint must be provided for each line up to five stories and basement in height, and for each additional five stories or fraction thereof one additional ounce of peppermint must be provided for each line.

1052. In most of the States of the Union there are State Boards of Health, who prescribe general rules and regulations for plumbing and drainage. Their regulations have all the force of other laws and can be enforced by heavy penalties. In fact, the State Boards of Health have more authority in such matters than the local governments, and every plumber should obtain a copy of their regulations.



GAS AND GAS FITTING.

THE USES OF GAS.

1053. The uses of gas for fuel and illumination have increased enormously within the last decade, and there is a general tendency among manufacturers, and also among domestic users, to employ gaseous fuel in preference to coal whenever practicable.

The advantages of gaseous fuel over all forms of solid fuel, in the way of convenience and freedom from dirt, are so great that its use is likely to become universal. It is now used for a variety of manufacturing operations, ranging from the delicate work of tempering hair springs for watches to the gigantic operations of glass melting and steel making.

In dwellings it is used to advantage for cooking, ironing, drying, heating water, and in recent years has been used successfully for house warming.

For direct heating, it is burned in gas stoves and fire-places, and for hot-water or hot-air heating, it is used in specially designed boilers and furnaces.

It also appears that gas lighting will be almost entirely accomplished by burning gas so as to produce *heat* instead of light, the heat being transformed into the desired light by means of auxiliary apparatus.

There is another circumstance which tends to increase the general use of gas, and that is the readiness with which it can, by means of suitable gas engines, be used to generate power. These motors are made in all sizes, from mere toys to engines of 500 horsepower; and, owing to their convenience and remarkable economy, their use is likely to become general.

The rapid development and extension of the uses of gas,

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both for heating purposes and illumination, renders it very necessary that the gas-fitter should have a thorough understanding of the principles of the combustion of gas, and of the development of heat and light thereby.

GAS SUPPLY AND DISTRIBUTION.

PIPES.

1054. The pipes which are used for the distribution of gas are made of a variety of materials, including cast and wrought iron, brass, lead, block tin, and "composition" (which is an alloy of lead, tin, and antimony); they are also made of rubber.

1055. Cast iron is usually employed for large pipes which are to be buried in the ground, such as street mains, etc. The pipes made of this material are liable to be of unequal density and texture, being close-grained and hard in some parts, and coarse-grained and spongy in others. They are also liable to be perforated by blow-holes and bubbles, which vary in size from minute pin-holes to hollow spaces as large as the hand, having only a thin crust of metal upon the inside and outside of the spaces. To detect these defects, all cast-iron pipe should be thoroughly inspected at the foundry where made. The presence of unsound iron or spongy places, or bubbles of any considerable size, will be revealed by the difference in the sound when tapped with a light hammer. Each pipe should also be subjected to a test by hydraulic pressure, to prove its tightness and strength.

If the grain of the iron be coarse and soft, the gas will gradually exude through the metal and leak away, although the pipe may be solid and strong. This defect is usually remedied by coating the pipe thoroughly, both inside and out, with asphaltum, or a mixture of asphaltum and tar. This coating also prevents the metal from rusting, and thus adds greatly to the durability of the pipe.

The proper mode of applying the coating is to dip the pipe while hot in a bath of melted asphaltum. If the metal

is not properly heated, the coating will not adhere with sufficient firmness, and will fail to penetrate and seal up the small defects of the pipe.

Standard cast-iron gas pipes, however, as placed on the market by the manufacturers, are usually uncoated; this is to avoid the use of unsound pipes, which might be made temporarily gas-tight by the asphaltum coating, which closes the pores or other imperfections.

1056. Wrought-iron pipe may be used under ground if it is thoroughly coated and protected against rust. It corrodes faster than cast iron under the same conditions, and its durability will depend mainly upon the care taken to protect it. The smaller sizes of pipe, such as those employed to connect the house pipes with the street mains, should always be galvanized if they run through damp places, and if they are buried in the ground, they should also be protected by an external coating of asphaltum of generous thickness.

When the pipe runs through cinders or coal ashes, the protective coating must be made of extra thickness to resist the corrosive action of the water which leaches through the cinders. The pipe should not only be coated with asphaltum in the usual manner, but should also be wrapped with two or more layers of coarse cloth, wound on spirally, and an outer coating of asphaltum applied hot, in sufficient quantity to thoroughly saturate the cloth and cover it.

Galvanizing alone is not a sufficient protection for pipes laid through ashes, or in ground which is permeated with salt or sea-water.

Wrought-iron pipe has an advantage over cast-iron pipe, inasmuch as the number of joints required in a given distance is much less.

Plain black wrought-iron pipe may be used without hesitation for all the interior piping of a building, except where its appearance would not be desirable.

1057. Lead pipe may be used for conveying gas both under ground and in buildings, but it is so easily distorted

and kinked that iron pipe is usually preferred. Lead pipe must be protected against corrosion where it comes in contact with cement or mortar, by wrapping it with building paper and coating it with asphaltum or hot tar.

Pipes which are made of lead, **block tin**, or **composition** have a very smooth interior surface which favors the flow of gas through them, and they are also capable of being easily bent to suit any position. But, owing to their flexibility, they must be supported on shelving, when extended horizontally, to prevent them from sagging, and thus forming low places which are liable to accumulate water.

The labor of making the necessary connections between soft pipes and the fixtures is greater than with iron pipe, and the first cost of the material is also greater; consequently, the use of soft-metal piping is usually dispensed with as far as practicable.

Soft-metal pipes are liable to be damaged or punctured by nails which may be driven through the woodwork near them, and sometimes holes will be gnawed into them by rats and mice. These little animals evidently like to use their teeth upon the soft metal, and they will occasionally gnaw a pipe without any other apparent reason.

1058. Pure rubber is not a suitable material for holding gas, because the gas will ooze through it and escape, just as water will ooze through wet paper. When rubber is used for the construction of gas bags and flexible tubing, it must be specially prepared in order to be gas-tight.

NAMES OF PIPES.

1059. The main supply pipes which are laid in the streets are called **mains**.

The branches which conduct gas from the mains to the house are called **service pipes** or **services**.

The pipes which convey the gas from the meter to the various parts of the building are called **distributing pipes**.

All vertical pipes are distinguished as **risers** or **drop**

pipes, according to the direction of the flow of gas within them. The flow is upwards in a "riser," and downwards in a "drop" pipe.

FITTINGS.

1060. The fittings employed in gas piping are generally similar to those made for steam and water, except that some of them are provided with lugs or flanges by which they can be firmly fastened to the walls and ceilings.

They should be made of malleable iron for all sizes up to 2 inches in diameter; for larger sizes, cast iron may be used. Galvanized fittings are to be preferred to plain iron fittings, because the coating of zinc will usually penetrate into any small pin-hole that may exist, and will effectually seal it against leakage.

1061. Defective fittings should not be employed in any case, and when one is discovered in use, it should be promptly removed, if possible, and be replaced with a perfect one. The practice of patching holes or defects in fittings or pipes with cement is a dangerous one, and should be condemned. The cost of replacing defective fittings with sound ones is so small in proportion to the damage that may be done by a leak, such as vitiating the air or suffocating some person, or causing an explosion or fire, that the gas-fitter is not justified in risking anything upon the durability and permanency of a cement patch. Such patches are especially unsafe if they are in the vicinity of steam or hot-water pipes or hot-air flues, or are near a hot chimney. The heat will soften the wax, and the gas pressure will slowly force it out of the hole.

1062. A variety of fittings especially designed for gas piping is shown in Fig. 369. They are made of malleable iron, and are known in the trade by the following names:

(a) Quarter elbow; (b) tee; (c) street elbow; (d) cross; (e) elbow with side outlet; (f) right and left coupling; (g) reducing coupling; (h) cap; (i) male and female extension piece; (j) plug; (k) waste nut; (l) drop elbow, female

screwed; (*m*) drop elbow with male screw; (*n*) drop tee with female screw; (*o*) drop tee with male screw; (*p*) drop elbow with male screw, flange left; (*q*) male chandelier loop; (*r*) drop elbow with long outlet piece; (*s*) chandelier

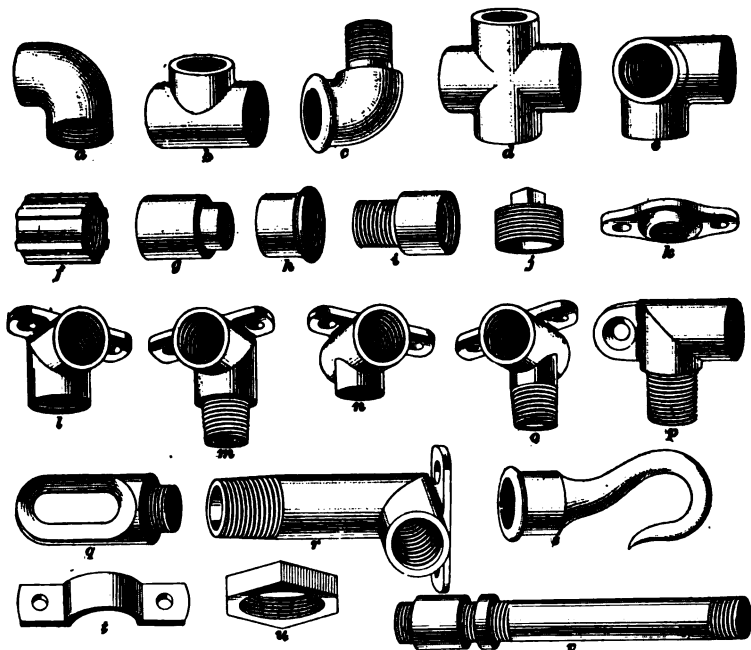


FIG. 369.

hook, female; (*t*) pipe strap, tinned; (*u*) locknut; (*v*) long screw. These flanged fittings can be had either right or left, also with male or female screws.

FLOW OF GAS.

1063. The flow of gas is governed by the same laws that govern the flow of other fluids. The **rate** of flow depends upon:

- 1st. The *area* of the pipe.
- 2d. The *length* of the pipe.
- 3d. The *pressure* of the gas.

4th. The *density* of the gas.

5th. The *number* and *class* of fittings in the length of the pipe.

1064. The volume delivered in a given time by a pipe of given area, the pressure and density of the gas remaining the same, will be *inversely* as the square root of the *length* of the pipe.

If the length, area, and density remain the same, the volume delivered will be *directly* as the square root of the *pressure*.

If the pressure, length, and area remain the same, the volume delivered will be *inversely* as the square root of the *density*.

1065. If the rate of flow through any certain length of pipe is known, the volume which will be delivered by a longer or shorter pipe of the same diameter, in the same time (the pressure and density of gas remaining the same), may be found by the following rule:

Rule.—*Multiply the volume delivered by the pipe of given length by the square root of that length, and divide the product by the square root of the proposed length. The quotient will be the delivery at the proposed length.*

EXAMPLE.—A certain pipe 50 feet long delivers 100 cubic feet of gas per hour; how much will it deliver if it be made 150 feet long?

SOLUTION.—The volume originally delivered is 100 cubic feet; multiplying this by $\sqrt{50}$, or 7.07, we have $100 \times 7.07 = 707$. Dividing this by $\sqrt{150}$, or 12.25 ($150 =$ proposed length), we have $707 \div 12.25 = 57.71$ cu. ft. Ans.

1066. The volume that will be delivered under different pressures may be computed by the following rule:

Rule.—*Multiply the volume delivered at the given pressure by the square root of the proposed pressure, and divide the product by the square root of the given pressure. The quotient will be the delivery at the proposed pressure.*

The pressure to be considered in each case is the excess of the pressure of the gas when it enters the pipe, above the pressure existing in the chamber into which it discharges;

or, in other words, it is the difference in pressures at the inlet and discharge of the pipe.

EXAMPLE.—A certain pipe discharges 100 cubic feet of gas per hour, from a reservoir having an internal pressure of 1.6 inches of water, into the atmosphere; what volume will be discharged per hour if the pressure be increased to 5 inches of water?

SOLUTION.—The volume discharged at the given pressure is 100 cu. ft.; multiplying this by $\sqrt[4]{5}$, or 2.236 (5 = proposed pressure), we have $100 \times 2.236 = 223.6$. Dividing this by the $\sqrt[4]{1.6}$, or 1.265, we have $223.6 \div 1.265 = 176.7$ cu. ft. Ans.

EXAMPLE.—A certain pipe delivers 80 cubic feet of gas per hour, from a main having an internal pressure of 2.4 inches of water; what pressure must be put upon the main to cause the pipe to deliver 150 cubic feet per hour?

SOLUTION.—As the quantities delivered are directly proportional to the square roots of the pressures, it follows that $80 : 150 :: \sqrt[4]{2.4} : \sqrt[4]{\text{proposed pressure}}$; hence, squaring *all* the terms of the proportion (which will not destroy it), $6,400 : 22,500 :: 2.4 : x$, $x = 8.44$ = pressure required in inches of water. Ans.

1067. The effect of variations in the density of the gas upon its flow may be computed by rule, Art. **1065**, by merely substituting the word *density* for the word *length*.

The foregoing rules apply only to the **theoretical flow** of gas under perfect conditions. In practice, perfect conditions are never attained; consequently, the actual flow of gas in pipes is less in volume than that computed by the rules given. The deficiency varies according to the amount of friction and other resistances within the pipe.

PRESSURE OF GAS.

1068. If the specific gravity of a gas is less than that of air at the same temperature, then the pressure will always be greatest at the top of the pipe or chamber which contains the gas. If the gas is heavier than air, then the greatest pressure will be at the bottom of the chamber which contains it.

The upward pressure of gas having a less density than

air is caused by the deficiency in its weight and its consequent inability to balance the pressure of the atmosphere.

For illustration, let us consider a column of gas 1 foot square and 100 feet high, having a density of .5, or one-half that of air, its temperature being the same as that of the atmosphere, say 60°. Now, air at 60° weighs .0764 pound per cubic foot, and a column containing 100 cubic feet will weigh $.0764 \times 100 = 7.64$ lb. The gas having a density of .5 will weigh only half as much, or 3.82 pounds, and is, therefore, unable to balance an equal volume of air. Consequently, it is pressed upwards with a force of $7.64 - 3.82 = 3.82$ lb. against the top of the chamber which contains it. Whatever the actual pressure of the gas may be at the bottom of the column, it will, in this case, be increased at the top to the extent of 3.82 pounds per square foot.

1069. The increase of pressure in each 10 feet of rise in pipes with gas of various densities is shown in the following table:

TABLE 40.

Rise in pressure	0.	.0147	.0293	.044	.058	.073	.088	.102
(Inches of water),								
Density of gas	1.	.9	.8	.7	.6	.5	.4	.3

EXAMPLE.—The pressure in the basement, at the meter, is 1.2 inches of water; what will be the pressure at the sixth story, 70 feet above, the density of the gas being .4?

SOLUTION.—The table shows that the increase will be .088 in. for each 10 feet of rise; therefore, $.088 \times 7 = .616$ in. increase. Then, pressure at sixth story $= 1.2 + .616 = 1.816$ in. Ans.

MEASURING PRESSURE OF GAS.

1070. The pressure of gas is measured by the same instruments as those used for air and other fluids. The construction of the instruments, however, is varied somewhat for convenience in handling.

The common **water gauge** is shown in Fig. 370. The

tube *a* is made of metal, and is provided with a socket *d* which will screw on to an ordinary fixture in the place of a burner. The tubes *b* and *c* are made of glass, and are filled with water up to the zero of the scale. The scale is graduated in inches and convenient fractions of an inch. The tube *c* is open to the air at the top. When pressure is admitted to the tube *a*, the water will sink in the tube *b*, and will rise in *c*. The difference in the height of the water in the two tubes, measured in inches, is the measure of the pressure exerted in *inches of water*. The depression below zero in *b* should be added to the rise above zero in *c*. The fall in one tube will not exactly equal the rise in the other unless the tubes are of exactly equal bore.



FIG. 370.

Water gauges are sometimes made with scales which are graduated to one-half of actual sizes, so that only the rise in one tube need be noted. An instrument which is graduated in that way must be held exactly plumb, and the water must stand exactly at zero at the start; otherwise it will be found that the rise and fall will not be equal, and must be averaged to get the true pressure.

For measuring heavier pressures, mercury may be used in the tubes instead of water.

1071. Mercurial gauges for gas-fitters' use are of two classes, namely, the *open-column gauge* and the *closed-column gauge*. An **open-column gauge** is shown in Fig. 371. The mercury is contained in an iron cup *h*, and the air or gas under pressure enters through the tube *i*. The glass tube *k* is packed or cemented airtight at *l*, and is protected by a tubular brass casing *m*. When the mercury rises in the glass tube, it also sinks in

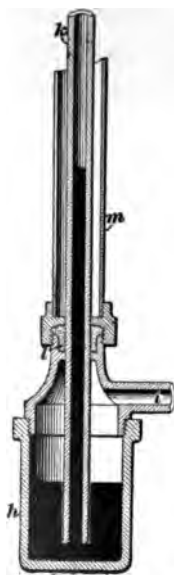


FIG. 371.

the cup, but to a much smaller extent. The graduations upon the brass casing indicate the difference of level in inches which exists between the mercury in the tube when standing at that height and the actual surface of the mercury in the cup. As this surface varies with every change in pressure, it follows that the graduations will not correspond with an ordinary scale of inches. With this apparatus the mercury will rise or fall about 2 inches in the tube for every pound difference in pressure in the mercury cup, because the glass tube is open to the atmosphere on top.

The chief objections to the open-column gauge are: 1st. The glass tubes must necessarily be so long, in order to secure the proper height of mercury column to resist a suitable testing pressure, that the tube invariably gets broken. 2d. The gauge is not self-contained, and the mercury is often spilled and lost. The open-column gauge, however, is very sensitive and reliable.

1072. A **closed-column gauge** is shown in Fig. 372. It is essentially composed of a chamber *a* and a glass tube *b*, having its top hermetically sealed and its lower end opening into *a* as shown. Two air chambers *c* and *d* are employed in the construction, the bore which joins these chambers being exceedingly small. A porous diaphragm is used at *e* which allows air to pass through it, but not the mercury. The apparatus is screwed on to the gas pipe system as at *f*, and it must hang plumb, as shown.

Before screwing on the gauge preparatory for a test it should be laid on its back until all the mercury which may be in *d* falls into *a*. This allows *c* and *d* to become entirely filled with air at atmospheric pressure, so that the mercury will not show in the tube until pressure is applied at *f*. When an air pressure is applied, it forces the mercury from

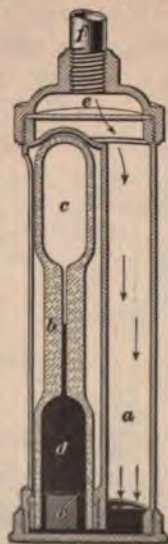


FIG. 372.

a into d , thereby compressing the air in the tube. The rise of the mercury in d , however, will be very slow until all the air in d is compressed into c and the mercury reaches the small bore, when its movement will be rapid because of the reduced sectional area of the current. If the pressure now remains constant in a the mercury will remain stationary in the small bore, as shown.

This form of gauge, although not quite as sensitive as the open-column gauge, is sensitive enough for the best class of work. The mercury in the small bore will fall about $1\frac{1}{2}$ inches for every pound fall of pressure in a , more or less, according to the ratio between the volume of c and d and the diameter of the small bore.

If a colored oil is used instead of mercury, this gauge will actually become almost too sensitive for practical purposes; the liquid would then drop about 2 inches for each $\frac{1}{10}$ of a pound decrease of pressure in a , more or less, according to the bore, as previously stated.

This gauge is not supposed to indicate the amount of pressure, but simply to indicate a fall of pressure, which indicates leaks in a gas-pipe system. For gas-fitters' use, these gauges are made to test at a pressure of 10 pounds per square inch only, unless the plug i is removed, when a test of 15 lb. per square inch can be obtained. Special tubes are required for testing at higher pressures. It will be observed that this gauge is self-contained and the glass is protected against damage.

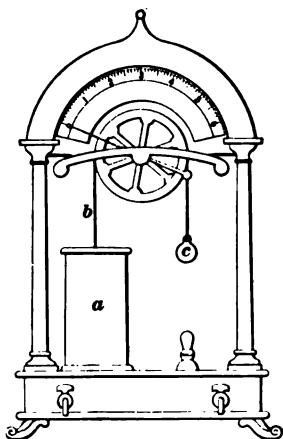


FIG. 373.

1073. The **arch gauge**, shown in Fig. 373, consists mainly of an inverted cup, which is partially submerged in water or other fluid contained in the cylinder a . The cup is suspended by a cord b , and is partly counterbalanced by a weight c . The cord passes over a wheel provided with a pointer which

travels over the scale on the "arch." When the pressure of the gas increases, it raises the cup correspondingly, and the pressure is indicated by the position of the pointer on the scale.

Pressures which have been measured in inches of water or mercury may be translated into pounds per square inch or square foot by multiplying the reading by the following figures:

One inch of water at $62^{\circ} = 5.2$ lb. per square foot.

One inch of water at $62^{\circ} = .0361$ lb. per square inch.

One inch of mercury at $62^{\circ} = .4897$ lb. per square inch.

Pressures per square inch or square foot may be converted into inches or feet of water, or inches of mercury, by multiplying the pressures by the following figures:

One pound per square foot = .1923 inch of water at 62° .

One pound per square inch = 27.7 inches of water at 62° .

One pound per square inch = 2.042 inches of mercury at 62° .

MEASURING THE FLOW OF GAS.

1074. The **velocity** of gas flowing through a pipe may be measured by means of **Pitot's tube**, which is shown in Fig. 374. It consists of two tubes *a* and *b*, which are secured in a suitable plug *c*. The lower end of *a* is square, but the end of *b* is curved to face the current, as shown. The upper ends of the tubes are connected to a water gauge *d*. The pressure which affects the gauge is due to the momentum of the gas which strikes the open end of the tube *b*. The velocity which corresponds to any certain indication of the water gauge may be

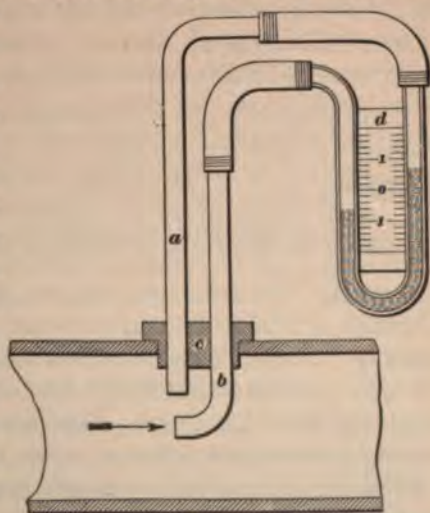


FIG. 374.

found by referring to the tables which are furnished by the maker of the instrument.

The **volume** of gas passing through a pipe in a given time is computed by multiplying the velocity, as found by Pitot's tube, by the area of the pipe.

1075. The actual **quantity** of the gas is computed by correcting the volume for temperature and pressure, reducing it to a volume at standard temperature of 32° and standard pressure of 1 inch of water. The correction for temperature may be made by use of

Rule I.—*Multiply the measured volume by the actual temperature plus 460, and divide the product by 492. The quotient will be the volume at 32°.*

The correction for pressure may be made by

Rule II.—*Multiply the volume by the pressure in inches of water plus 407, and divide the product by 408. The quotient will be the volume at 1 inch pressure.*

EXAMPLE.—A certain pipe passes 1,000 cubic feet of gas per hour, under a pressure of 8 inches of water; what will the volume be when the pressure is reduced to 1 inch, the temperature remaining the same?

SOLUTION.—Applying rule II,

$$1,000 \times (8 + 407) \div 408 = 1,017.1 \text{ cu. ft. Ans.}$$

In dealing with gas it is necessary to keep in mind a clear distinction between the *apparent volume* of the gas and the *actual quantity*. The former is the volume as measured at the actual temperature and pressure, while the latter is the volume of the same gas at standard temperature and pressure.

1076. For ordinary purposes, the volume of gas passing through a pipe is measured by an apparatus called a **gas meter**. A gas meter measures the *volume* only, and its indications are not affected by any change that may occur in the pressure of the gas. Gas is used at the burners at a nearly uniform low pressure, while the pressure in the street mains often varies 3 or 4 inches per day. Consequently, a gas meter is a very inaccurate instrument for measuring the *actual quantity* of gas supplied.

Usually the gas meter is adjusted to measure correctly *at a certain pressure*, and that pressure is intended to be the *average* pressure of the gas in the mains in the locality where the meter is used. Although the mechanism of the meter may be perfectly accurate, yet if the pressure for which it is adjusted does not correspond with the *actual* average pressure in the mains, it will necessarily give incorrect measurements.

The adjustment is made in the following way: It is shown in the example given in Art. **1075**, that 1,000 cubic feet of gas at 8 inches pressure, becomes 1,017.1 cubic feet when reduced to 1 inch pressure. In the case of a meter which is to measure gas at 8 inches, the registering mechanism is adjusted to indicate 1,017.1 cubic feet, when the measuring apparatus has really passed but 1,000 cubic feet.

If a meter thus adjusted to 8 inches pressure should be used to measure gas having a pressure of only 1 inch, it would indicate *too much* to the extent of 17.1 cubic feet per thousand.

The *excess* thus indicated by any meter which is adjusted to a pressure differing from the true pressure will be about 2.45 cubic feet per thousand for each inch of difference in pressures. The difficulty thus encountered in correctly measuring the volume of gas actually delivered under varying pressures is easily overcome by using a *governor* between the meter and the street main or service pipe. The **governor** is a species of reducing valve which will receive gas at any pressure, whether steady or variable, and discharge it at a steady low pressure. A governor is described in Art. **1081**.

MEASURING THE VOLUME OF GAS.

1077. Meters for measuring the volume of gas have been constructed in many ways. The varieties which are most in use at the present time are shown in Figs. 375, 376, and 377.

The **wet meter** is shown in Fig. 375. The measuring

is done by means of a revolving cylinder which is divided by partitions into four chambers *b*, *c*, *d*, and *e*. The gas enters through a pipe *a*,

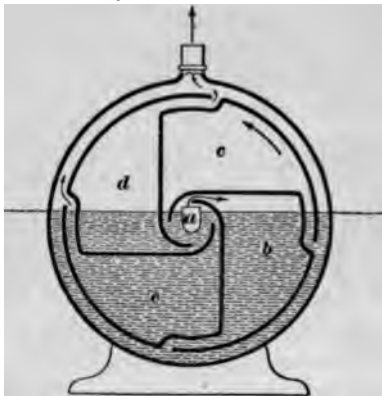


FIG. 378.

which opens just above the surface of the water. The inner ends of the partitions are curved so that they dip under the water and prevent the fresh gas from entering into any other chamber than the one which is rising out of the water. In the figure gas is beginning to fill the

chamber *b*, and it is discharging freely from the chamber *d* into the outer casing to which the discharge pipe is attached. The outlet of chamber *c* is still under water and no gas can escape from it until the cylinder turns over a little farther. The filling and emptying of the chambers continue as long as any gas is passing through the meter.

The capacity of each chamber depends upon the level of the water within it; consequently, the water must be kept exactly at a proper level at all times to enable the meter to measure accurately. The axis of the cylinder must be made strictly horizontal, otherwise the capacity of the chambers will be increased and the meter will indicate less than the true volume passing through. The water will evaporate and pass off as vapor along with the gas, and, unless replenished, the meter will become more and more inaccurate, until finally the gas will pass through without registering at all. Many dishonest persons have taken advantage of the fact that by tipping the meter so that one end of the cylinder is considerably higher than the other, the water may be made to uncover the inlet and outlet openings of a chamber at the same time, thus permitting the gas to pass through without turning the cylinder or registering.

The best forms of wet meters are provided with a float attachment which automatically closes the gas inlet when

the water-line is too high or too low, thus obtaining a reasonably uniform measuring capacity in the meter, and preventing a passage of gas without a corresponding movement of the drum.

The wet meter is sufficiently accurate if kept in good order, but owing to the defects mentioned, it is now but little used for measuring the amount of gas supplied to consumers. But it is still employed at gas works in preference to all others to measure the total amount of gas produced. For this purpose it is constructed of large dimensions, and is provided with glass gauges by which the level of the water may be observed and accurately controlled. It is then called a **station meter**.

1078. An ordinary variety of **dry meter** is shown in Fig. 376. The measuring is done by means of two **bellows**

a and *b*, which are inflated and emptied in alternation. The meter case is divided into three chambers, the upper one containing the valves *c* and *d* and the registering mechanism. The body of the case is divided by a partition *e* into two equal chambers, each of which contains one of the bellows. Each bellows consists of a large circular plate *f* which is supported by attachments to the vertical rock-shaft *g*, and a flexible ring or diaphragm *h*, having one edge secured to the plate *f* and the other to the middle partition *e*. The rock-shafts *g* are connected at the top by arms and links to a central crank *k*. The throw or stroke of the plates *f* is thus limited to an exact distance, and the relative movements of the two bellows are so timed that the

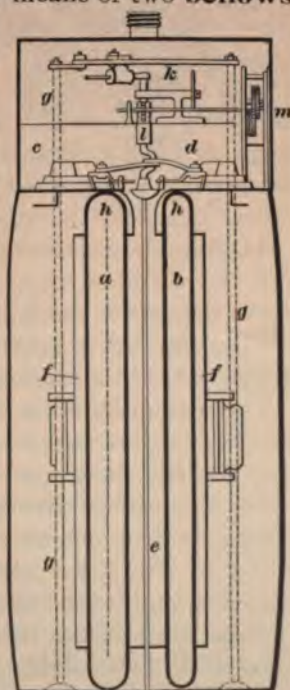


FIG. 376.

movement of gas through them is steady and nearly uniform. The interior and exterior spaces of the two bellows constitute four measuring chambers, and the gas is admitted to and released from them in rotation, by the movement of the slide valves *c* and *d*. These valves are moved by means of links connected to the crank on the lower end of the central shaft *l*. The amount of gas passed through by each bellows at one revolution of the shaft nearly equals the area of the circle filled by the leather ring *h* multiplied by the actual distance through which the plate *f* is moved, or twice its stroke.

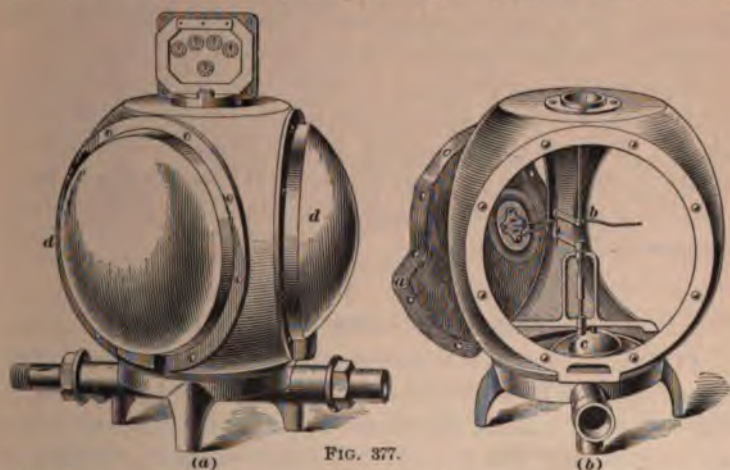
The capacity of the meter is regulated by adjusting the radius of the crank *k*, and thus changing the length of the stroke of the bellows. The rotations of the shaft are recorded by the registering mechanism at *m*, and the volume passed through is indicated in cubic feet.

The rings or diaphragms *h* are usually made of fine leather. After long service these rings are liable to become hard and stiff, and to crack. To keep them in good serviceable condition, they must be oiled at intervals. When the meter is used for gas which has not been properly purified, the leather rings are liable to become coated with tarry matter, and thus be spoiled.

1079. Dry meters are also made with three diaphragms, and the diaphragms are sometimes made square. A dry meter designed especially for natural gas and high pressures is shown in Fig. 377, (*a*) being an external view, and (*b*) an inside view of the working parts.

Three diaphragms *a* are employed, each one being connected by a link to the central crank *b*. The diaphragms are single-acting, that is, they displace gas only when they move outwards into the chambers enclosed by the covers *d*. The central or main chamber is filled with gas at full pressure at all times. The gas is admitted and released from the measuring chambers behind the diaphragms by means of a hollow circular slide valve *c*, which is attached to the crank on the lower end of the central shaft. When gas is admitted to a measuring chamber, the diaphragm is balanced, having an

equal pressure on each side, and it moves inwards in obedience to the crank, without resistance, thus filling the chamber behind it. But when the valve cuts off the fresh gas and opens a duct into the delivery pipe, the pressure in the central chamber exceeds that in the delivery pipe, and the diaphragm is driven outwards, expelling the gas from the measuring



chamber. Thus the measuring chambers are filled and emptied in regular rotation. The shape of the meter being spherical, it can endure high pressures without distortion or any impairment of its accuracy.

All gas meters require a certain small amount of power to operate them; consequently, the pressure of the gas will be slightly reduced in passing through the meter. In the ordinary size used in dwellings, the reduction of pressure usually amounts to about .2 inch of water, sometimes more. When gas is supplied at very low pressure, it becomes difficult to use a meter, because the resistance which it offers diminishes the pressure at the burners to such an extent that the gas will not burn well.

Thus, if gas is furnished at a pressure of .5 inch and the resistance of the meter is .2, then the gas passing to the burners will have a pressure of only .3 inch, and will burn in such a languid way that it will be very unsatisfactory.

The numbers usually affixed to gas meters indicate the number of gas burners consuming five cubic feet each per hour which the meter will supply with ease and certainty. In practice the number of burners may be increased one-third above the number on the meter.

Gas meters should not be exposed to a lower temperature than 40° , nor a higher temperature than 100° , since the oiled leather in the diaphragms will be injuriously affected thereby.

The internal condition of a meter can be ascertained by noting the difference in pressure in the supply and delivery pipes. A water gauge should be attached to each pipe as close to the meter as practicable. If the gauges show a difference greater than .2 inch in pressure, the meter should be removed and repaired.

READING GAS METERS.

1080. Fig. 378 is a diagram of a meter dial of the ordinary type. When the pointers all point to the zero mark on their respective dials, the meter is said to be at zero. If the meter is at zero and a certain volume of gas is allowed to

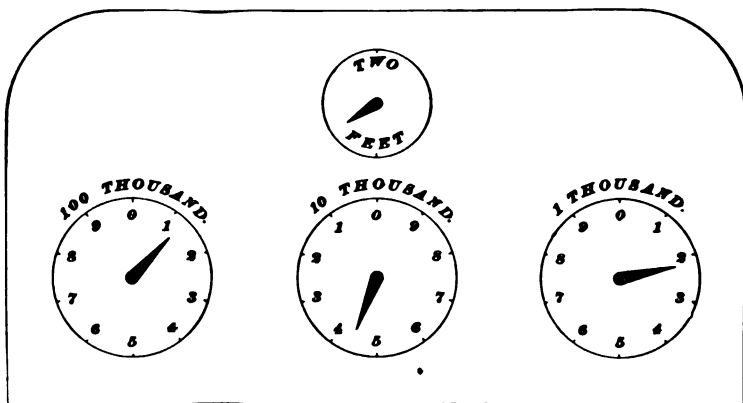


FIG. 378.

pass through it, the number of cubic feet of gas passing through the meter will be indicated on the dials. If the meter is not zero, however, the number of cubic feet of gas

which has actually passed through during the time specified is equal to the difference between the number indicated upon the dials before the gas was allowed to flow through the meter, and that indicated when the gas has flowed through.

The top dial is marked *two feet*, which means that when two cubic feet of gas have passed through the meter the pointer on this dial will have made one revolution.

When 1,000 cubic feet of gas have passed through the meter, the pointer of the dial to the right, which is marked *1 thousand*, will have made one complete revolution, and the pointer of the middle, or *10 thousand* dial, will have moved from 0 to 1. When the pointer to the right has made another revolution, the pointer of the middle dial will have moved from 1 to 2, which means that two complete revolutions of the pointer to the right have been made. When the middle pointer has made one complete revolution, the pointer to the left will have moved from 0 to 1 on the *100 thousand* dial, which means that $\frac{1}{10}$ of 100,000, or 10,000 cubic feet, have passed through the meter.

To read a meter dial of this description, first write down the figure which the pointer has just passed on each dial, then annex two ciphers to the right; the number so obtained will be the amount of gas in cubic feet which the meter has measured.

Thus, the pointers on the diagram (Fig. 378) indicate that 14,200 cubic feet of gas have passed through the meter. When the pointer to the left has made one complete revolution, the process of indicating is repeated. The pointers all move from the smaller to the larger figures, just like the hands of a clock.

REGULATION OF GAS PRESSURE.

1081. Pressure regulators for gas, also called **gas governors**, are designed to receive gas at a high and variable pressure, and to deliver it at a lower, but steady pressure. In principle, they belong to the general class of automatic reducing valves.

A regulator suitable for large pipes or mains is shown in Fig. 379. It consists of a hollow cylinder or drum *a*,

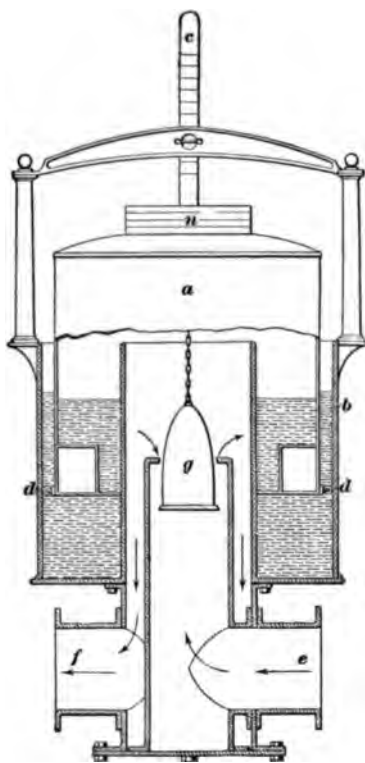


FIG. 379.

which floats in water within the tank *b*. The drum is guided by means of a rod *c* at the top and rollers *d* at the bottom. The gas is brought in through the pipe *e* and is discharged at *f*. The passage of the gas is controlled by the conical valve *g*, which is attached by a rod to the top of the drum *a*. A very slight increase in the pressure of the gas within the drum and pipe *f* will cause the drum to lift and reduce the opening of the valve *g*, thus checking the inflow of gas. Similarly, if the pressure should fall, the drum would sink and increase the opening of the valve until the pressure in the delivery pipe rose to the point for which the regulator was adjusted. The pressure in the delivery pipe may be deter-

mined by increasing or diminishing the weights at *n*.

It will be seen that the pressure in the delivery pipe is not exactly constant; but the variation is confined within such narrow limits that the purpose of regulation is accomplished with sufficient accuracy for all ordinary uses.

Small regulators for domestic use are constructed upon the same principle. Water is unsuitable for small regulators because it evaporates so easily. In many instances glycerine is used in place of water, since it will not evaporate at any ordinary temperature. Mercury is also used with complete success.

1082. Another variety of regulators is made in which the floating drum is replaced by a flexible diaphragm *a*, as shown in Fig. 380. This diaphragm rises and falls with the variations in pressure in the delivery pipe, and operates the valve *b* in the same manner as the floating drum in Fig. 379. This variety of regulator is called a **dry governor**. These governors are used upon the gas pipes. Both varieties of governors are, however, made of sufficiently small dimensions to control single gas-burners, and are frequently united with them in the same structure.

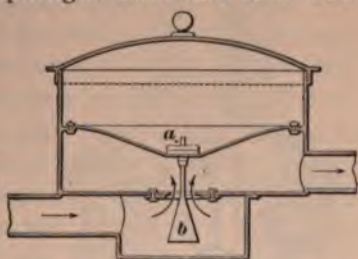


FIG. 380.

1083. A very successful burner containing a **wet governor** is shown in Fig. 381. The gas passes upwards through the valve seat *a* into the interior of an inverted cup *b*, which floats in glycerine *d*, contained in the lower part of the shell *c*. It escapes from the floating cup through two small holes, which are made of a size that will pass the desired quantity of gas which the burner is intended to consume per hour, at a pressure of .5 inch of water. If the pressure within the cup exceeds that amount, the cup will rise and partially close the valve. It thus maintains the pressure at the tip very close to .5 inch at all times, and ensures a steady rate of consumption, although the pressure in the pipes may fluctuate through 20 inches or more.

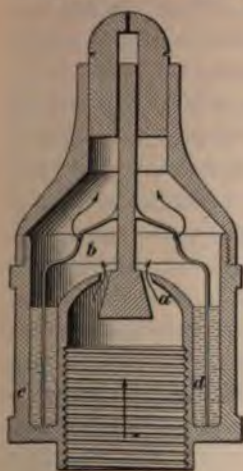


FIG. 381.

1084. One of the most improved forms of dry governors for single gas-burners is shown in Fig. 382. It is called a **volumetric regulator**. The flow of gas to the burner

tip is controlled by a tubular valve *a*, which closes against a seat *b*, and which is attached to a very light disk *d*. This disk moves up and down freely, like a piston, in the cylindrical chamber *c*, being guided also by the central post. Gas is admitted freely to the under side of the disk, and a certain quantity is permitted to pass around to the upper side through the hole *e*. The capacity of this hole may be changed by means of the regulating screw *f*. The weight of the disk and valve is made such that it will require a certain excess of pressure on its under side, say $\frac{1}{4}$ inch, to lift it. When it begins to rise, there is nothing to stop its upward movement or to prevent the valve *a* from closing the outlet except the circumstance that, as the outlet becomes choked, the pressure above the disk increases until it approximates or equals the pressure below it. The excess of pressure on its under side is thus diminished, and is no longer sufficient to hold it up; consequently, it will gradually drop and increase the outlet opening until the pressure above the disk becomes $\frac{1}{4}$ inch less than that below it. Thus, the *pressure* of the gas escaping past the valve to the burner will always equal the difference in pressure on the upper and lower sides of the disk, in this case about .5 inch; and the *volume* will depend upon the size of the orifice as determined by the screw *f*. By adjusting this screw, the governor can be arranged to deliver gas in any volume within its scope.

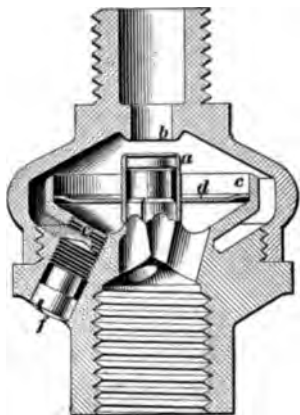


FIG. 382.

ward movement or to prevent the valve *a* from closing the outlet except the circumstance that, as the outlet becomes choked, the pressure above the disk increases until it approximates or equals the pressure below it. The excess of pressure on its under side is thus diminished, and is no longer sufficient to hold it up; consequently, it will gradually drop and increase the outlet opening until the pressure above the disk becomes $\frac{1}{4}$ inch less than that below it. Thus, the *pressure* of the gas escaping past the valve to the burner will always equal the difference in pressure on the upper and lower sides of the disk, in this case about .5 inch; and the *volume* will depend upon the size of the orifice as determined by the screw *f*. By adjusting this screw, the governor can be arranged to deliver gas in any volume within its scope.

1085. It should be observed that there is a radical difference in the effect produced by the two classes of governors described. The governors shown in Figs. 379 and 380 operate only to regulate the *pressure* in the delivery pipes; they do not limit or control the *volume* of the gas

passing through. They will pass enough gas to maintain the pressure, no matter whether the amount be ten feet per hour or a thousand.

The governors shown in Figs. 381 and 382 not only control the *pressure* of the gas which is delivered to the burner, but they determine the *volume*, also, with great exactness. The gas is compelled in each case to pass through fixed orifices, which will, of course, pass only a certain volume per hour at the pressure for which they are adjusted. Any attempt to increase or diminish the *volume* passing instantly changes the internal pressure and causes the regulating valve to move.

PRESSURE.

1086. The objects sought in the use of pressure regulators or governors are, first, *economy* in the consumption of gas, and, secondly, *steadiness* of the lights and the most *effective operation* of the burners.

A burner which is designed to consume say 5 cubic feet of gas per hour will work most efficiently when it is supplied with just that quantity—neither more nor less. If only 4 cubic feet are supplied, the flame will be dull and smoky, and the amount of light will be considerably less than that produced by a 4-foot burner using the same gas. If 6 cubic feet be forced through the burner, the flame will flare and jump, and the light given off will be less than that produced by a 6-foot burner.

If the volume of gas passed through a burner considerably exceeds the amount it was designed to burn, some of the excess will pass through without being burned, and will contaminate the air of the room in which it is used.

It is of great importance, therefore, that both the volume and pressure at the burners should be closely regulated. The amount of gas wasted by overpressure is much greater than generally known. A good, new lava tip burner consuming 5 cubic feet per hour at .5-inch pressure will consume about .5 of a cubic foot more for each increase of .1 inch in the pressure. Thus, an overpressure of .1 inch will increase the gas bill about 10 per cent.

The variation in the gas pressure, even in the best regulated systems, is usually much greater than one-tenth inch, frequently ten-tenths and more.

1087. There are two systems of gas regulation now in vogue, which are called, respectively, **pressure regulation** and **volumetric regulation**. In the first system, a governor is attached to the service pipe at the meter, and the house distributing pipes are maintained at a constant amount; in the second system, *each burner* is supplied with a governor, and the pressure in the house pipes is not controlled, being about the same as in the mains.

In applying the system of *pressure regulation*, a number of difficulties are encountered which prevent the attainment of a satisfactory degree of success. If the system of distributing pipes be extensive, the resistance will be so great that it will be impracticable to maintain a uniform pressure throughout the system. If the burners at the extreme end of the system are supplied at a proper pressure, then those which are nearer to the meter will suffer from overpressure, and will waste the gas.

If the pressure is right for the burners on the first floor of a building, it will be too high for those on the upper floors. In very high buildings this difficulty is met by employing a governor on each floor. But if the floor areas are extensive, the resistance of the pipes will cause a difference in pressure at various points, and the burners near the governor will waste gas from overpressure, while those at the far end of the system will only be sufficiently supplied.

The attempt to overcome these difficulties by using **check burners** is often made, but it is found to be impracticable. The checks can not be adjusted to the requirements of each burner, except by an expenditure of time and labor that usually can not be allowed; and being composed of fine wire gauze or a wad of cotton, they are soon fouled and clogged by the impurities carried with the gas.

1088. The system of *volumetric regulation* is free from all these difficulties. No governors are required on the house

pipe or service pipe; the pressure may be the same as in the street main, and it may fluctuate to any extent, provided that it never falls too low to supply enough gas. Under this system every burner has its own governor, and if the regulators are properly adjusted, each burner will have the proper amount of gas at just the right pressure to enable it to produce light in the most economical manner. While the system of pressure regulation is far more economical than the use of check burners without other regulation, yet it can not regulate the pressure and volume with the nicety that is required for successful lighting. The volumetric system is to be preferred in all cases.

There is a use, however, for a pressure regulator on the service pipe, which may be of importance in some situations. A meter can not measure accurately if the pressure varies any considerable amount, as before explained. Therefore, if it happens that accuracy of measurement at the meter be of great importance, a regulator or governor may be placed between the meter and the street main.

The *proper place* for a pressure regulator, if one be used, is between the meter and the main. The meter should then be adjusted to suit the house pressure instead of the street pressure.

The ordinary practice is to put the governor on the house side of the meter, and to use a meter that is adjusted to what is supposed to be the *average* pressure in the street main. This average is usually mere guesswork. The arrangement has no advantages, and is inferior to that recommended above.

The pressure which should be given to the gas at the burners, in order to secure the best results, varies greatly in different forms of apparatus. The following are the pressures generally used:

Argand burners.....	.2 inch of water.
Common batwing burners	.5 inch of water.
Welsbach incandescent burners.....	.5 or more.
Wenham and Lebrun lamps.....	.5 to 1 or more.
Atmospheric burners	1.0 or more.

PIPING BUILDINGS.

SIZE OF PIPES.

1089. The capacity of each pipe must be great enough to properly supply all the burners which receive gas through it, when every burner is in full operation. Allowance must also be made for all heating and cooking apparatus, not only for that which is decided upon, but for all that is liable to be required.

Service pipes should never be less than $\frac{1}{4}$ inch in diameter, because of the liability to chokage, and it is advisable to make the diameter at least 1 inch if the pipe is of iron. For small cook stoves, the supply pipe should be at least $\frac{1}{4}$ inch in diameter, and larger stoves should have pipes 1 to $1\frac{1}{2}$ inches in diameter.

In computing the quantity of gas required for lighting purposes, one *burner* may be reckoned as consuming 5 cubic feet of gas per hour, unless otherwise stated in the specifications. The quantity actually required by burners of modern and improved construction, however, differs so much from that of the common forms that it is impracticable to compute the volume of gas required by merely noting the number of burners.

Having ascertained the probable maximum quantity of gas required in cubic feet per hour, the necessary diameter of the pipe can be found from Table 41. If the length of the proposed pipe exceeds the maximum length given in the table, then the diameter chosen should be the next size larger. Considerable judgment is required in using this table. For instance, suppose that 550 cubic feet of coal gas are required to be delivered in one hour through a pipe 100 feet long, we find that $1\frac{1}{2}$ -inch pipe would be large enough, because, while the quantity to be delivered is 50 cubic feet in excess of that given in the table, the length of the pipe is 50 feet shorter than the maximum length allowed. If the pressure of gas exceeds 2 inches of water, the principal pipes may be reduced in diameter one size. If the pressure is less than one inch of water, then all the

pipes must be made one size larger, and in case of very long pipes, or very low pressure, say about .5 to .8 inch of water, the diameter will require to be increased still more.

When carbureted air, or **gasoline gas**, is used, no distributing pipe should be less than $\frac{3}{8}$ inch in diameter.

The use of the table is shown by the following:

EXAMPLE.—What diameter of pipe should be used to supply three ordinary burners, the length being 60 feet?

SOLUTION.—The quantity consumed will be $3 \times 5 = 15$ cu. ft. per hour. The table shows that $\frac{3}{8}$ -inch pipe can be depended upon to deliver that quantity of gas at a distance of 20 feet only; therefore, it will not serve properly to carry 60 feet. The $\frac{1}{2}$ -inch pipe is evidently too large; therefore, the intermediate size— $\frac{3}{4}$ inch in diameter—may be used. **Ans.**

TABLE 41.
CAPACITY OF GAS PIPES.

Diameter of Pipe.	Maximum Length.	Capacity per Hour.	
		Coal Gas.	Gasoline Gas.
Inches.	Feet.	Cubic Feet.	Cubic Feet.
$\frac{1}{4}$	6	10	
$\frac{3}{8}$	20	15	10
$\frac{1}{2}$	30	30	20
$\frac{3}{4}$	50	100	75
1	70	175	125
$1\frac{1}{4}$	100	300	200
$1\frac{1}{2}$	150	500	350
2	200	1,000	700
$2\frac{1}{2}$	300	1,500	1,100
3	450	2,250	1,500
4	600	3,750	2,500

The pressure of the gas is assumed in the foregoing table to be about two inches of water. It should be understood that the quantities given are those which the pipes will deliver at the burners *without objectionable fall of pressure*.

PIPE FITTING.

1090. The proper methods of cutting, bending, and threading pipes, together with the proper modes of jointing and supporting them, are fully explained in Arts. **691 to 695, 739 to 746, 783 to 797, and 809 to 825**, and it is unnecessary to add anything to the instructions there given. It should be borne in mind, however, that the tightness of all screwed joints should depend upon the perfection of the screw threads, and not upon any red lead or cement that may be used in closing the joint. Therefore, all threading tools should be kept sharp and in strictly good order at all times.

In **cutting threads** on small pipes at the pipe vise, the pipe should not project any further than is necessary to give elbow room while working the dies, because the further away the dies are from the vise, the greater is the torsional stress upon the pipe, and the more liable it is to be strained or split in the butt-welded joint.

It is customary to cut and thread all the pipes required for an ordinary building upon the premises where they are used, and to do the work exclusively with hand tools. A great saving of labor and time can be made by doing this work in the shop, leaving only the crooked or special fitting to be done by hand. If the working plans are made with reasonable accuracy, there will be no difficulty in preparing the pipes and fittings at the shop, so that they may be put into their places in the building and screwed together with entire success.

In **screwing pipes together**, or into fittings, the pipe should be gripped as close to the fitting as practicable so as to prevent the pipe from being split by twisting.

After pipes are cut and threaded, each piece should be closely inspected to see whether it is free from cracks or splits, and to see whether its length conforms to the drawing.

DRAINAGE OF PIPES.

1091. Illuminating gas nearly always contains a small percentage of watery vapor, and this condenses upon the

interior of the pipe. The water of condensation will flow to the lowest point in the pipe, and if no provision is made for its removal, it will accumulate to such an extent as to close the passage and stop the flow of gas. Therefore, all horizontal pipes, unless very short, must be so inclined that they will drain properly. All the branches of a riser must be inclined to drain back into it, or, if the branch be very long, it may be inclined so as to drain into a drip cup at some intermediate point. Usually the whole system of house pipes is arranged to drain back into a drip cup at the meter. In Fig. 388, *D* indicates a **drip cup**, or **siphon**, to receive the water from the service pipe *C*, and *I* and *K* are drip cups for the two house pipes.

Drip cups must always be located at some point where they can be got at and emptied without difficulty.

Gas pipes composed of lead or other soft metal must be guarded against *sagging* by running them upon a ledge or shelf. Every sag operates as a pocket to collect water, and if the depression of one of the sags equals the diameter of the pipe, the accumulation of water will eventually choke the pipe and stop the flow of gas.

GAS-FITTERS' PLANS.

1092. The location of gas fixtures is generally indicated on the architect's plans by a star, thus *, and the number of burners on each fixture, together with the height of the fixture above the floor, is stated in the specifications.

To facilitate the work of running the pipes and of estimating their proper sizes, the gas-fitter should make plans of the piping on each floor. An outline tracing should be made of each floor of the building from the architect's plans. On these should be noted the position of each fixture and its height from the floor, and the number of burners required for each one.

The number of burners and the kind of fixture may be conveniently indicated by the symbols shown in Fig. 383. *A*, *B*, and *C* represent side lights or brackets having 1, 2, and 3 lights, respectively, each large dot representing a

burner. In a similar manner, *D*, *E*, *F*, *G*, *H*, and *I* represent drop lights having 1, 2, 3, 4, 5, and 6 burners, respectively.

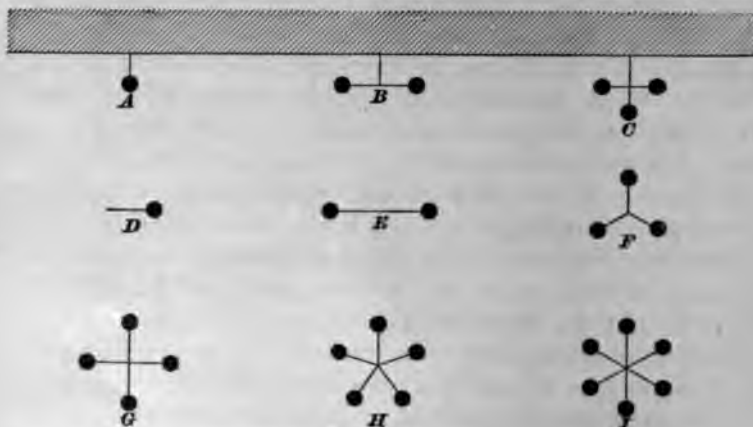


FIG. 383.

ively. The manner of using these symbols is exemplified by the plans, Figs. 385 and 386.

The horizontal piping should be indicated by plain black lines, and each floor plan should show only those pipes which are to be actually run in the floor of that story, or upon the under side of it.

The points at which risers or drop pipes are to be connected to the horizontal pipes should be indicated as shown

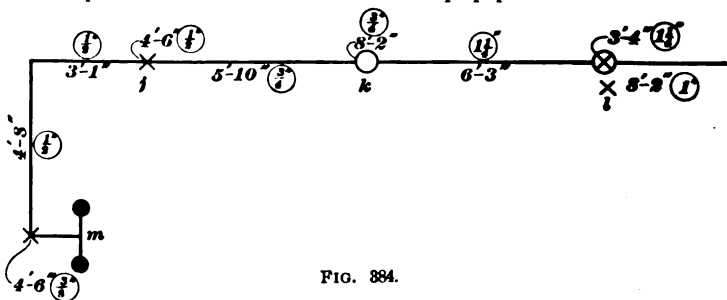


FIG. 384.

in Fig. 384. Thus, an $\times$ at *j* indicates that a drop pipe descends from that point, and a $\circ$ at *k* indicates that a riser ascends from that point. A $\circ$ and $\times$, combined as at *l*, indicate that the vertical pipe extends both above and below.

At *m* is indicated a drop pipe leading to a bracket or side light having two burners.

The length of each pipe should be figured from center to center of fittings, and the diameter should be written close to the figures indicating the length. Thus, the pipe between *l* and *k* is shown to be $1\frac{1}{4}$ inches in diameter and 6 feet 3 inches between centers of fittings.

The length of each riser or drop pipe should be similarly indicated by figures placed near the symbol, and connected to it by a light line; thus, at *j* we have a drop pipe $\frac{1}{2}$ inch in diameter, descending 4 feet 6 inches to center of fitting; at *k* we have a riser $\frac{3}{4}$ inch in diameter, ascending 8 feet 2 inches; at *l* we have a riser $1\frac{1}{4}$ inches in diameter, ascending 3 feet 4 inches, and a drop pipe 1 inch in diameter, descending 8 feet 2 inches.

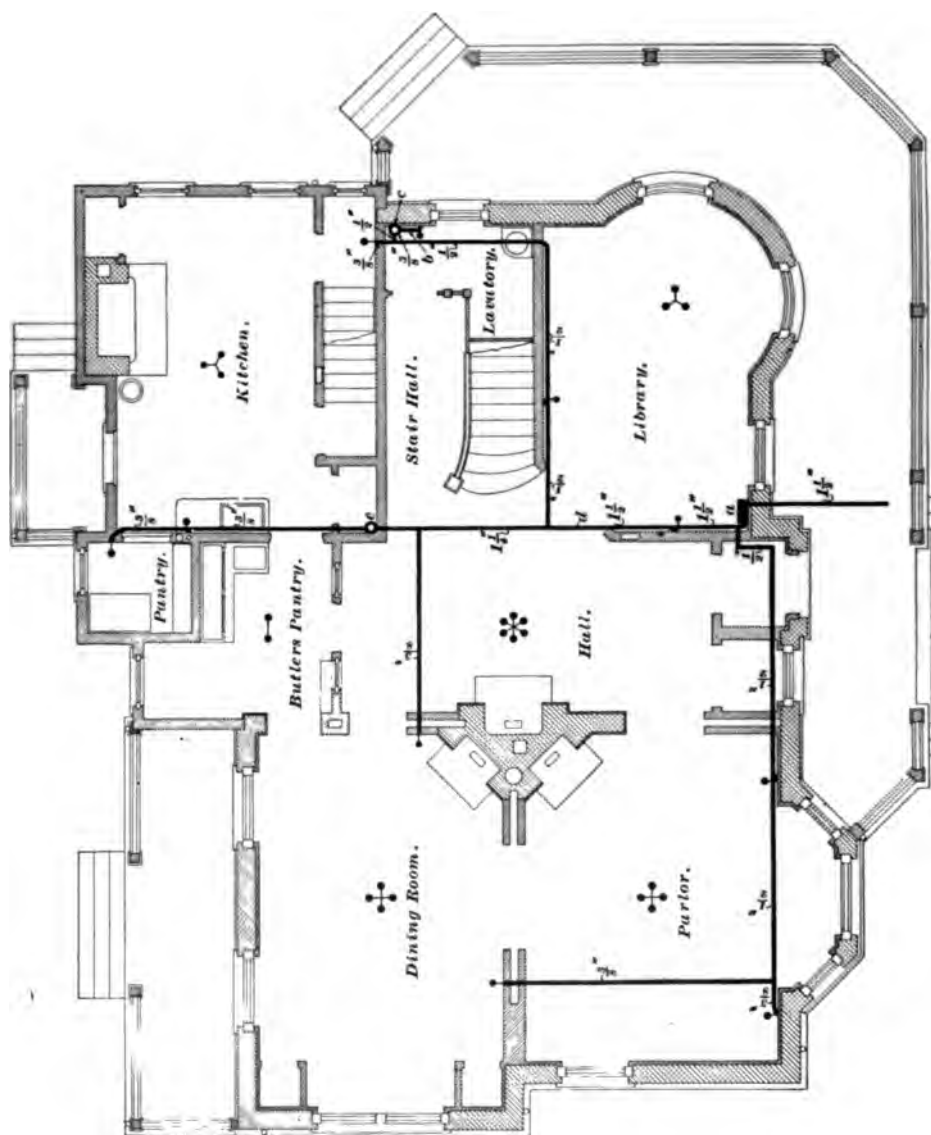
In order to show which figures belong to the drop pipe at *l*, it is necessary to place a $\times$ before them, as shown. Where figures are crowded, it is advisable to draw a O around the figures, indicating diameters of pipes, in order to clearly distinguish them from all others.

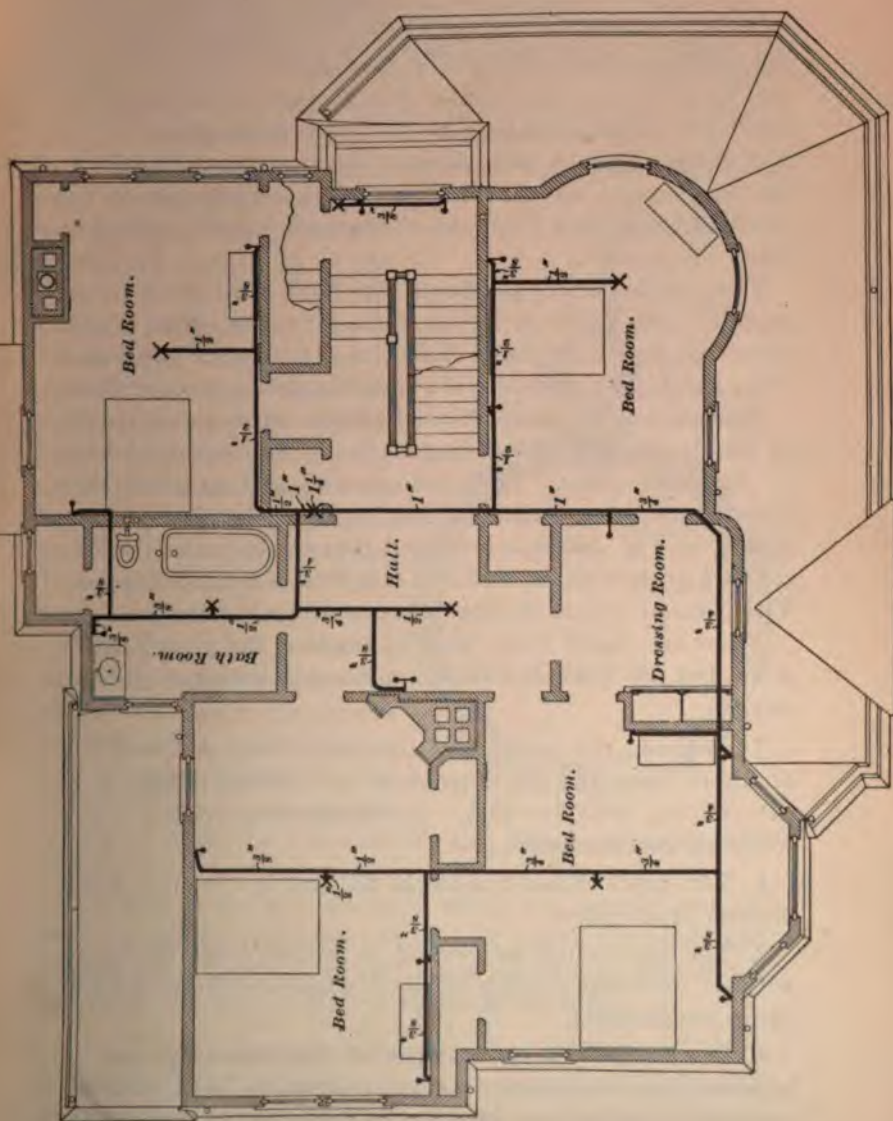
If any of the vertical pipes require to be offset or bent to pass around obstructions, etc., or a horizontal pipe requires to be run along a wall at a height between the floor and the ceiling, a reference letter should be placed conspicuously at that point, and a corresponding note made upon the margin of the drawing. A diagram of the special pipe required should be made and attached to the drawing.

Gas-fitters' plans are sometimes made in perspective; but if the work is at all complicated, the drawing is likely to be very confusing, especially if the draftsman is a little unskilful.

The plan recommended above has the advantage that several sets of piping for various purposes may be indicated upon the same drawing. Thus, pipes for gas, steam, and water, and tubing for electric wires may be shown by using differently colored inks for the various systems of pipe.

1093. Fig. 385 shows the first floor plan of a common two-story and basement dwelling house. The second story plan is shown in Fig. 386. These figures are supposed to





represent tracings from the architect's drawings with the gas piping drawn in.

The meter *a* is placed in the basement, and all the piping shown on this plan is run along or under the basement ceiling, except *b*, which is a $\frac{3}{8}$ -inch horizontal branch to supply the lavatory bracket from a $\frac{3}{8}$ -inch riser *c*, run from the basement to the brackets on the stair landing above. A distributing main *d* runs directly from the meter outlet to the riser *c*, and all the branches which supply gas to the brackets of the first floor, also the basement lights, are taken from this pipe.

The chandeliers or pendants which illumine this floor are supplied with gas from the pipes shown in Fig. 386. These pipes run under the floors and across or between the joists. They also supply all brackets which illumine the second floor.

The pipes are all proportioned to give an abundant supply of gas to the entire building when all the jets are burning at the same time. They are also all laid to pitch back towards the meter, where a drip cup may be placed. The piping in Fig. 386 is so arranged that no floor joists will be cut at a greater distance than 2 feet from a point of support. The joists all run from front to rear of the building.

There are many other ways of running the pipes for this work, but the drawings show a method probably as good as any.

1094. If the location of the pipes is not shown by the architect, then the gas-fitter must use his own judgment in determining their position. He should be governed by the following considerations:

1. The pipes should run to the fixtures in the most *direct* manner practicable.
2. The pipes must be *graded* to secure proper drainage, without excessive cutting of floor-beams or otherwise damaging the building.
3. Pipes which run crossways of floor-beams should be laid not more than one foot away from the wall, so as to avoid serious injury to the floor, as explained in Art. 839,

4. Fixtures should be supplied by risers rather than by drop pipes, as far as practicable.

5. All pipes should be located where they can be got at for repairs with the least possible damage to the floors or walls.

CONNECTIONS TO STREET MAINS.

1095. The pipes which convey the gas from the mains into the building, commonly called service pipes, should be connected to the top of the main as shown in Fig. 387, and not to the side or bottom of the pipe. They should be inclined so that they will drain into the main. If that can not be done, then they should be inclined towards the building, and should be provided with a suitable drip cup from which the water may be conveniently drawn off.

A shut-off cock should be placed in every service pipe at the curb, and this should be enclosed in a suitable box extending upwards to the surface of the pavement, and closed against the entrance of dirt, water, or snow by a tight cover.

The hole in the wall through which the service pipe enters the cellar or basement should be larger than the pipe, so that the settlement or shifting of the ground outside will not cause the pipe to bind or strain in the hole.

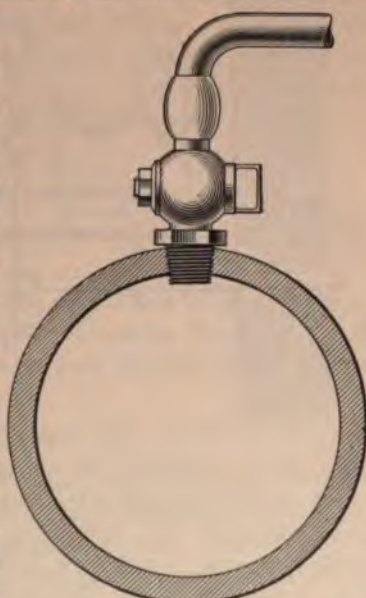


FIG. 387.

CONNECTIONS TO METERS.

1096. The connection from the meter to the service pipe and also to the house pipe should be made with lead or other soft metal tubing, as shown at *J*, Fig. 388. These

connections will bend and relieve the couplings on the meter from injurious strains in case the pipes expand or contract, or are displaced by the settlement of the building, etc.

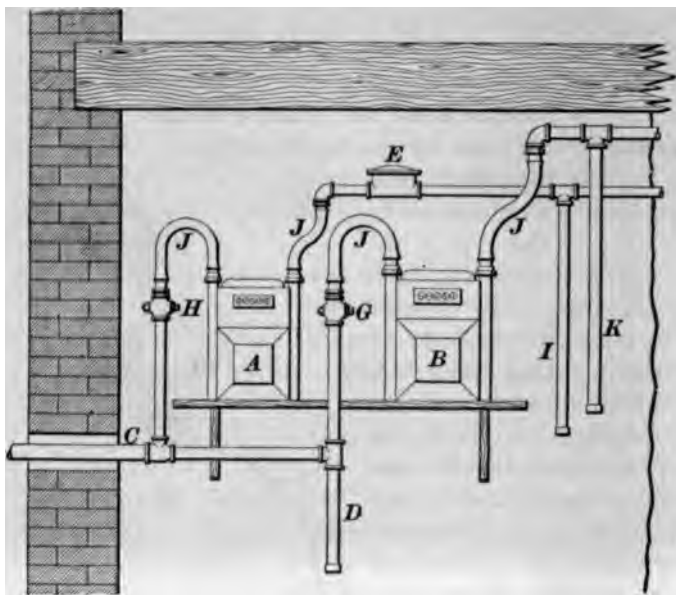


FIG. 388.

Meters are usually set upon a shelf, but this is not necessary unless the meter is large and heavy. If the meter is of the *wet* variety, then it must be supported upon a shelf, and the shelf must be carefully leveled both lengthways and crossways. The *dry meters* now in common use do not require leveling in order to work properly, but they should always be set plumb for the sake of appearance, and as a matter of good workmanship.

A single service pipe may supply two or more systems of distributing pipes, as shown in Fig. 388. Each meter must be provided with a shut-off cock, as at *H* and *G*, and drip cups should be attached to each line of house pipes, as at *I* and *K*. The service pipe should also have a drip cup, as shown at *D*, unless it is inclined so as to drain into the street main. If several meters are used in the same building, they

should be placed upon a shelf, in one group if practicable, and all of the connections should be made exactly alike, so as to present a neat and orderly appearance.

When gas is used for fuel in addition to lighting, it is often required that the two supplies be measured separately, in order to determine the actual expense for each purpose. Some gas companies furnish gas for fuel at reduced rates to induce consumers to put in cooking apparatus, and also to increase the sale of gas. If the price of gas is the same for all uses, and it is not desired to keep a separate account of that used for fuel, then one meter is sufficient to measure the entire supply.

ORDER OF OPERATIONS.

1097. The proper way to pipe an ordinary building for gas is as follows:

1. The gas-fitter should visit each floor of the building with the plans in hand, and should mark the location of each drop to a hanging fixture, and of each side light or bracket.

2. Having thus acquired a clear idea of the location of each fixture, the next thing to be decided is the best route for the distributing pipes. If there are other pipes in the building, for water, or steam, or drainage, care should be taken to avoid conflict with them, and the risers for gas should be placed along with the other risers, unless they are at an inconvenient distance away. Pipes for the various purposes of heating, lighting, etc., should not be scattered promiscuously over a building, but they should be kept together as much as practicable.

3. The matter of drainage should next be considered. Each branch must drain back into its riser, and the whole system should drain back to the meter. Long branches which run crossways of the floor-beams should be avoided, because the notches which must be cut in the beams to give the necessary drainage become too deep, and are very objectionable.

4. Working plans of the piping on each floor, like Fig 384, should next be made for use at the pipe vise. The proposed route for each pipe should then be inspected to see whether the pipes can be got into place without difficulty, and whether right and left connections are required, and, if so, where they must be placed.

5. The roads for the various pipes should next be marked off, taking the carpenter along and explaining to him the depth to be given to the notches, etc., and he should be fully instructed where and how to build the supports for the hanging fixtures. If the walls are of brick, the necessary pockets for rising pipes, if any, should be marked off, and the proper places for cutting holes through the walls, etc., should be carefully marked and shown to the mason.

1098. Leaving the carpenter or mason to prepare the roads for the pipes, work may be begun by setting up the pipe vise and getting the tools ready.

Each piece of pipe should then be inspected to see whether it is free from obstruction and dirt. The several pieces of pipe are then cut and threaded according to measurements on the working plan, and the fittings screwed on while the pipe is in the vise. The various pipes should then be carried to their respective floors, and laid in convenient places.

Erection may be begun by fitting up the main riser. The various branches should then be extended, working always from the riser towards the outlets. Cement or red lead should be used very sparingly, and care should be taken that no lumps or clots of it run down into the inside of the pipes.

Elbows, T's, and other fittings should stand clear from the studding and joist, whenever practicable, so that all the joints may be accessible for the purpose of testing.

Changes in the direction of small pipes should be made by bending the tube, if practicable, instead of using an elbow. Elbows and other fittings to which side lights or brackets are attached should be provided with flanges or lugs, and should be firmly secured with screws to solid woodwork, or,

in case of brick walls, to wooden plugs driven into holes drilled in the wall, or to wooden blocks imbedded in the wall for that purpose, so that the fixture will not wobble.

The nipple for a side light or bracket should project from the wall at a true right angle to a distance of not less than $\frac{3}{4}$ inch, and not more than $1\frac{1}{4}$ inches. The nipple should be screwed tightly into the fitting, and a cap should be screwed on the outer end of it. This cap should be screwed up with only a moderate force, so that it can be easily removed at any time without danger of loosening the nipple from the fitting.

Drop nipples, which are to support chandeliers or other hanging fixtures, should hang perfectly plumb, and in case of a flat ceiling should project from $\frac{3}{4}$ inch to $1\frac{1}{4}$ inches from the surface. If ornamental center pieces of plaster, etc., are to be used, the necessary extra length of the nipple should be ascertained from the architect or contractor.

1099. The proper mode of supporting a hanging fixture is shown in Fig. 389. The weight of the fixture is carried

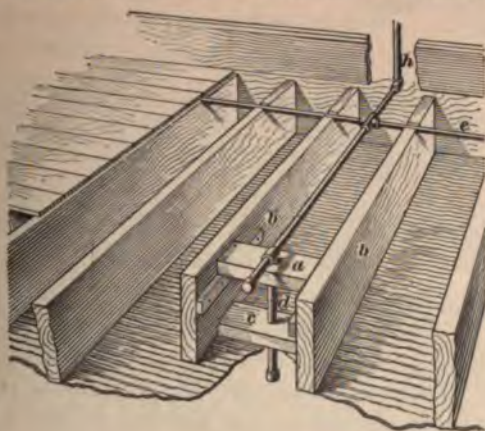


FIG. 389.

by the wooden block *a*, which must be made strong and be well secured to the joists *b*, *b*. The lower block *c* serves to guide the drop piece *d* and prevent it from swinging in any

direction. Care should be taken to make the drop piece perfectly plumb.

When the nipples or drops for the fixtures are all in place, they should be tested to determine if they are square with the wall. This may be done by attaching a straight piece of pipe a foot or so long to which the square and level may be applied, or a plumb-bob may be used.

The gas pipes should be placed in a new building as soon as the walls are up and the rough timbers of the floors and partitions set, but before the floors are laid or the lathing done. When a gas pipe runs parallel with the floor boards, as shown at *c* in Fig. 389, the board which covers it should have the lower flange of the groove removed, so that it can be readily taken up when desired. If the pipe runs crossways of the floor boards, a loose piece should be provided in the floor over every principal elbow or T, so that they can be got at easily in case of repairs or leakage. The loose boards and covers should be fastened in place with $2\frac{1}{4}$ -inch screws. Brass screws are frequently used for that purpose, as they will not rust.

EXPOSED PIPES.

1100. Gas pipes should not be exposed to the weather, if possible to avoid it, and care must be taken to protect them from freezing winds or air currents. The moisture will condense upon the interior of the pipe and form ice, and the deposit will increase in thickness until the pipe becomes choked. Exposed pipes should be covered with hair felt or other good non-conducting material, which should be made thoroughly water-proof by a covering of painted canvas. Good protection is especially necessary if the pipe contains carbureted air or gasoline gas.

Iron gas pipes should not be allowed to touch lead pipes or electric wires which run crossways or near them, because the continual shifting caused by changes in temperature will ultimately wear a groove or thin spot in the softer pipe, and the insulation of the electric wire will be cut through, thus making a "ground" or "short circuit."

If a metal pipe runs within two inches of an electric wire, they should be separated by a non-conductor of some description. For example, the pipe may be wrapped with four or five layers of rubber tape.

TESTING A SYSTEM OF PIPES.

1101. As soon as the pipes are all in place and are properly secured, the system should be tested to find whether it is perfectly gas-tight. The instruments required for making the test are described in Arts. **1071** and **1072**.

A convenient nipple should be selected for making an attachment to the proving pump; and every other nipple and open end should be tightly closed by screw-caps. Plugs driven into the ends of pipes will not answer the purpose.

The pump and pressure gauge may then be connected to the system and made tight. Air should be forced in until the gauge indicates 15 or 20 inches of mercury, or 7 to 10 pounds per square inch if the mercury column is open to the atmosphere on top. The pump should then be shut off, leaving the gauge under pressure. If the mercury remains stationary in the glass for five minutes, or if the column of mercury does not fall more than 1 inch per hour in either of the gauges shown in Figs. 371 and 372, the system may be considered satisfactorily tight. In large jobs a fall of $\frac{1}{2}$ inch per hour should be the limit.

The extent of the leak may be judged by the rapidity of the fall in pressure, but its location must be found by the sense of smell.

For this purpose, a small quantity of ether should be introduced into the pipes. The pressure gauge may be provided with an ether cup especially for testing purposes; but if it is not, a T and plug should be provided to receive the ether. The ether may then be poured directly into the pipe, and the plug replaced as quickly as possible. The pressure should then be pumped up as before. The odor of the ether will diffuse throughout the system of piping and will escape from the leak; thus the location of the leak will be revealed by the smell of ether.

1102. To locate the leak, it is necessary to carefully examine the pipe system, smelling each joint and suspected pipe or fitting. When a suspicious place is found, it should be daubed over with a thick solution of soap, and if any air is escaping at that point it will show itself by blowing soap bubbles.

Every leak that can be detected should be marked with chalk, and the pressure may then be let off. All defective pipes or fittings should be removed and replaced with perfect ones. Patching should never be permitted in first-class buildings. Gas-fitters' cement, which is so commonly used for patching up poor fittings, is only a coarse grade of sealing wax, and is not a proper material for closing up leaks in gas pipes or fittings.

If fittings are cracked, they should in all cases be removed. Cracked or split pipes should always be removed; it is useless to try to patch them.

After making all required changes, the pressure should again be applied, the test being repeated until, with a pressure of at least 15 inches of mercury, the gauge will show the system to be satisfactorily tight. The gas-fitter should aim to have the mercury remain perfectly stationary for an hour or more; and on a really high-class piece of work, the mercury column should stand all night without showing any appreciable fall in the morning.

In case of large buildings, it is advisable to test the piping in sections, say one floor at a time, since in this way it is much easier to locate leaks. After each section is tested, they may be connected, and then subjected to a final test.

The pipes should not be covered until the tests are completed. Usually the gas companies or the city authorities require that the testing be done in the presence of their inspector. If no such regulations are in force, then the owner or architect should witness the tests, so as to avoid any possible disputes.

1103. **Ether** is a dangerous fluid to handle, because its vapor is very volatile and explosive. Lighted cigars,

pipes, etc., must be removed from the vicinity of the ether bottle to prevent explosion. Great care must be taken to avoid spilling any ether on the hands or clothes, because if the odor is thus set free in the building, it will be difficult to detect leaks in the pipes. Other substances may be used which are free from the danger of fire, such as the *essential oil of peppermint* (not the "essence"), but they are not so volatile and do not diffuse throughout the pipes so readily.

1104. The **proving pump** is shown in Fig. 390. It is a single-acting piston pump, having an inlet valve at the

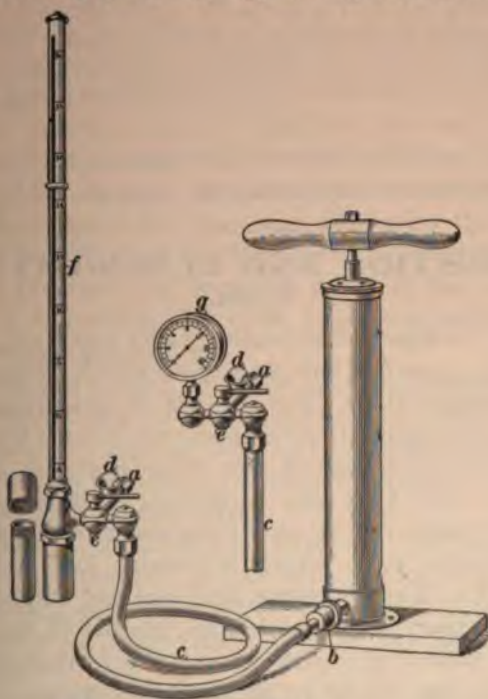


FIG. 390.

bottom which admits air under the piston, and an outlet or check-valve at *b*. The socket *a* of a special bracket is attached to a nipple on the pipe system which is to be tested. The pump is connected to the bracket by means of

a stout rubber hose *c*, which must be wired on to the coupling tails to prevent it from being blown off by the air pressure. The cock *e* serves to connect or shut off the pump from the pipe system, but does not shut off the gauge. The **ether cup** consists of a small funnel on the bracket at *d*, which is closed by a thumb-screw. This is for the purpose of introducing ether to make a pungent odor in the interior of the pipes. The pressure is shown by a mercurial gauge *f*, by a common steam gauge *g*, or by the gauge shown in Fig. 372.

The mercury column is to be preferred to the steam gauge, because its operation is positive at all times, and it always indicates the true pressure in the system.

Steam gauges, or other contrivances fitted with mechanical action, are not perfectly reliable pressure indicators; the moving parts are liable to stick fast, and slight pressure variations are not always indicated upon the dials.

COMBUSTION AND LUMINOSITY OF GAS.

1105. Ordinary illuminating gas is a mixture of several compounds of *carbon* and *hydrogen*, which vary somewhat in their composition. The process of **combustion** consists in the decomposition of these compounds by means of heat, and the formation of new compounds by combining the carbon and hydrogen separately with *oxygen*. The carbon and oxygen unite and form **carbon dioxide** (also called carbonic acid), which is usually indicated by the symbol CO_2 . The hydrogen and oxygen unite and form **watery vapor**, indicated by the symbol H_2O . A large amount of heat is given off during the formation of these compounds; but, owing to the mixed composition of ordinary illuminating gas, it is somewhat difficult to calculate the heat developed by its combustion.

1106. If the composition of the gas is known, and the actual weight of a given quantity can be ascertained, then the heat may be computed by assigning to each pound of

combustible substance the amounts given in the following table:

	Heat Units.
Hydrogen, burned to water, H_2O	62,000
Carbon, burned to carbon dioxide, CO_2	14,500
Carbon, burned to carbon monoxide, CO	4,400
Carbon monoxide, burned to carbon dioxide, CO_2 ..	10,100

Before gas can be burned, its temperature must be raised to the *point of ignition*. A part of the heat produced by combustion is always absorbed in thus preparing the cold gas and air for burning. Combustion is not *instantaneous* in any case, because an appreciable interval of time is always required to bring the gas and air up to the required temperature.

1107. The **temperature** of a gas flame varies according to the amount of combustion which takes place within a given space and time, and also upon the temperature of the gas and air at the moment of entering the burner.

Thus, if the size of a flame be reduced, the amount of combustion remaining the same, the temperature will be correspondingly augmented.

If a jet of gas be ignited in the ordinary atmosphere, the flame will spread out until the surface presented to the air becomes large enough to take up the oxygen required for combustion with sufficient rapidity to consume the gas as fast as it issues from the burner.

The *surface* of the flame thus extended is so large in proportion to the quantity of gas actually burning that the heat is radiated and imparted to the surrounding air with great rapidity, and the temperature of the flame is low in consequence.

If the flame be a large one, some of the gas will become cooled below the point of ignition before it can secure the oxygen necessary for combustion, and will fail to burn. The gas thus unburned is not only wasted and lost, but it mingles with and poisons the air of the room in which the burner is used.

The temperature of a gas flame may be increased by placing a chimney over or around the flame. The supply of oxygen is thus increased by the draft, and the size of the flame is reduced; or, if the supply of gas be increased, a greater amount may be burned in the same space.

Another method which is very effective is to mix the gas with the air required for combustion before burning it. Each particle of gas is thus supplied with the necessary oxygen, and it burns as fast as the temperature can be raised to the point of ignition. The volume of the flame is thus reduced to a minimum, and, consequently, the temperature is raised almost to the maximum. The burners employed for this mode of combustion are called **atmospheric burners**.

When the air, or gas, or both, are heated before they are burned, the heat thus imparted is added to the ordinary heat of combustion, thereby increasing the temperature of the flame.

When the pre-heating of the air or gas is accomplished by means of the waste heat of the products of combustion, the process is called **regeneration**.

This process is extensively used for producing high temperatures, and for lights of great intensity. The mode of applying it to gas lamps is shown in the Wenham and Lebrun lamps, Figs. 396 and 397.

LUMINOSITY OF GAS FLAMES.

1108. The luminosity of flames depends upon the manner in which the carbon is burned. Thus, when gas is burned in a good batswing or Argand burner, light is emitted profusely; but when it is burned in an atmospheric burner the flame appears pale blue and almost destitute of light.

In order to understand the cause of the great difference in luminosity in these cases, it is necessary to examine the structure of the flames and note the different conditions under which the carbon is burned. Hydrogen gives off an enormous amount of heat in burning, with very little light.

It serves to produce light, however, by heating the carbon which accompanies it, to incandescence.

If the flame of a candle be observed, it will be seen to consist of four parts, as shown in Fig. 391. The lowest part *a* is of a bright blue color, and emits very little light. The central part of the flame, marked *CH*, is composed of gas, generated from the material of the candle by heat, and it is dark colored or transparent. It is surrounded by a shell, or envelope, of yellow luminous flame, which is marked *C* and H_2O . Outside of this is another layer, marked CO_2 , which consists of hot gas, and is almost invisible.



FIG. 391.

The greater part of the oxygen, which moves from the surrounding atmosphere towards the interior of the flame, is intercepted in the outer layer of hot gas, and is united with the carbon which escapes outwards from the luminous layer, thus forming CO_2 . The remainder of the oxygen passes inwards into the luminous layer of the flame. Here it encounters the hot hydrocarbon gas which is passing outwards from the central space. The quantity of the oxygen is not sufficient to combine with both the hydrogen and the carbon. It combines with hydrogen easier than with carbon; consequently, the hydrogen is taken from the compound, leaving the carbon free and uncombined.

The intense heat generated by the burning hydrogen raises the temperature of the free carbon so high that it becomes brilliantly incandescent. This is the only part of the process of combustion that generates light of any consequence. This incandescence endures only while the carbon is passing from the central part of the flame to the outer layer—a very minute interval of time.

1109. The luminosity of the flame is thus seen to depend upon the momentary existence of the carbon in a state of entire freedom, at a high temperature, under circumstances which deprive it of oxygen. The moment that

it receives enough oxygen, it passes into carbon dioxide, and ceases to be luminous. Thus, the carbon is burned only in the outer, non-luminous part of the flame, and only hydrogen is burned in the luminous part.

Now, when gas is mixed with air and is burned in an atmospheric burner, each particle of carbon is accompanied with enough oxygen to convert it into carbon dioxide, and the hydrogen is similarly provided for. They burn simultaneously, the hydrogen forming water, H_2O , and the carbon passing directly from the original hydrocarbon compound into a new combination, CO_2 . It is not for a moment detached and maintained as free carbon, as in the candle flame; consequently, the opportunity to become incandescent and luminous never occurs. Therefore, the flame of an atmospheric, or Bunsen, burner emits very little light.

An open gas flame will lose much of its luminosity if its surface is made too large. When the pressure is too high the gas is projected so far into the atmosphere that a considerable part of it finds enough oxygen to burn its carbon and hydrogen simultaneously, as in a Bunsen flame. All that part of the gas which burns in this manner fails to emit light of any consequence.

1110. A gas flame will *smoke* when the area of its outer surface is so small that it can not take up oxygen from the atmosphere with sufficient rapidity to oxidize the carbon as fast as it arrives at the outer surface of the flame. Only a part of the carbon can then be oxidized; the remainder cools below the point of ignition and passes off into the air as suspended carbon or smoke.

The trouble may be remedied by increasing the area of the flame. This is usually accomplished by increasing the pressure of the gas. An artificial draft, such as made by a chimney or a fan, will also cure the smokiness by increasing the supply of oxygen to the flame.

1111. The *intensity* of the light emitted by a flame of any certain kind of gas depends upon the area of the *surface* of the flame, and upon the *temperature* developed by

the combustion. Thus, if we compare two burners which produce flames of different *sizes* while using the same pressure and volume of gas per hour, it will be found that the smaller flame will emit the most brilliant light. This result is due to the decrease of luminous surface from which light is radiated, which simply means a more rapid surface combustion per unit of area.

Again, if we compare two flames which are alike except in temperature, it will be found that the hottest flame will emit the largest volume of light.

In comparing the light produced by burning gases of different compositions, it is found that the greatest light is afforded by the gas which has the *largest amount of carbon in proportion to its hydrogen*. Thus, acetylene, which has twelve times as much carbon as hydrogen by weight, gives about fifteen times as much light as an equal volume of average coal gas.

When gas is mixed with air before burning, the color and brilliancy of the flame undergo a great change. If common illuminating gas is used and the maximum proportion of air is supplied the flame will be very small and pale, having a bluish top and a greenish center. But when the air supply is scant, the flame will burn with a dull yellow light, and will tend to smoke. As long as the yellow flame can be seen, the operator may be certain that the proportion of air is too small.

Other gases give characteristic colors when burned. When free carbon is burned to carbon monoxide, CO , the flame is of a bright blue color, and when carbon monoxide is burned to carbon dioxide, CO_2 , the flame shows a characteristic pink or rose color; but when the carbon is burned to carbon dioxide directly, the flame is nearly colorless.

The proportion of air which must be mixed with gas to secure good combustion varies with the kind of gas used, and also with the quality of the gas. Ordinary illuminating gas requires from six to twelve volumes of air to one of gas.

MODES OF PRODUCING LIGHT.

1112. All of the methods of producing light from gas or oils which are now in vogue depend upon the incandescence of some substance which is exposed to the heat of the flame.

In the flame of an ordinary gas burner, the light depends upon the incandescence of the carbon, which exists for a moment in a free state, as before explained.

There are other materials, notably lime, magnesia, zirconia, and the oxides of several of the earthy metals, which emit far more light than carbon when they are heated to incandescence. These materials are used in the **calcium light**, the **oxy-hydrogen light**, and in the **incandescent gas lamp**.

In the calcium light, a block of lime is raised to a very high temperature by means of a strong blowpipe, which is supplied with a mixture of common illuminating gas and air. The lime becomes incandescent and emits light of great brilliancy.

In the oxy-hydrogen light, pure oxygen and hydrogen are burned at the blowpipe, instead of ordinary illuminating gas and air. The heat of the flame thus produced exceeds all other known temperatures, and it causes the lime to glow with the most intense brilliancy.

Incandescent gas lamps are constructed in many ways, but all of them operate upon the same principle. Any sort of combustible gas, or even oily vapor, is mingled with air and is burned in an ordinary atmospheric or Bunsen burner, with the object of producing the greatest practicable heat. The flame is directed against the inside of a fine circular netting, which is composed of platinum wire or of threads of magnesia, zirconia, or similar oxides of the earthy metals. The netting becomes incandescent, and emits light of high intensity.

There are also three distinct methods of producing light by **electricity**—the arc light, the incandescent thread, and the vacuum tube. But these belong entirely to the department of electricity, and can not be described here.

GAS BURNERS FOR LIGHTING PURPOSES.

1113. The common **fish-tail**, or **union-jet**, burner is shown at *A* in Fig. 392. The gas issues from the orifices shown, in two round jets, which collide and spread out into a flat two-pointed flame, of the general shape shown. This shape is not so favorable to the development of light as that shown at *B* in the same figure, and as the holes rapidly become fouled, the burner soon loses its adjustment and becomes a very inferior fixture.

1114. The **batswing** burner, shown at *B*, Fig. 392, is the best variety of this kind now in general use. The

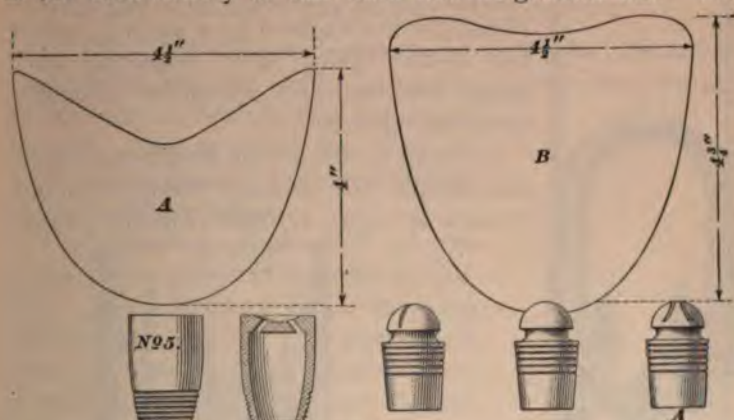


FIG. 392.

head of the tip is hemispherical, and the gas issues through a single straight slit which spreads it out into a thin flat sheet of flame, of the general shape shown at *B*. These burner tips are sometimes made with two curved slits, as shown by the tip at the right of the figure, but they are necessarily so thin and narrow that they are very easily clogged and spoiled.

The capacity of these burners, in cubic feet of gas per hour, is marked either by figures stamped upon them, or by means of grooves cut around them—one ring for each cubic foot. These marks serve to show the capacity only in the most general way, and can not be relied upon for accuracy.

1115. The **Argand** burner, which is shown in Fig. 393, is so named after its inventor. The burner consists of a hollow ring *a*, which is attached by two hollow arms *b* to a socket *c*, which is threaded to screw on to an ordinary burner nipple. The gas issues from the interior of the ring through a series of small holes *d*, and the jets all unite to form a complete circle of flame. A plentiful supply of air passes up through perforations in the chimney holder *e*, and also through the central hole of the burner. The volume of the gas is regulated by a screw *g*, which has a very quick pitch, requiring only about one-third of a revolution to nearly close the valve *h*.



FIG. 393.

be of such diameter and length that the draft will supply the proper amount of air to completely burn the gas—no more or less. This amount will vary somewhat with different qualities of gas.

Every Argand burner should have a volumetric regulator. Without it they are

In order to secure the best results with this burner, the pressure should be about .2 inch of water, and the chimney *f* must

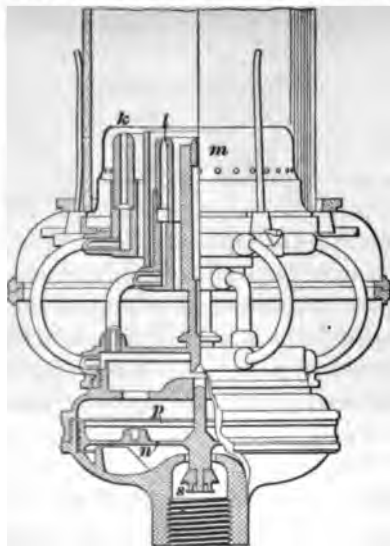


FIG. 394.

liable to be wasteful, while, if they are properly regulated and adjusted, they will burn gas very economically.

1116. Fig. 394 shows a large **compound Argand** burner, having two burner rings *k* and *l* and a single jet *m* in the center. This kind of burner is made with three, and even four, burner rings, the latter size serving to produce a light of 400 candle power. All of these compound burners are supplied with a volumetric pressure regulator, as shown. The gas passes through fixed orifices *n* in the floating governor disk *p*. The movement of this disk opens and closes the throttling valve *s*, and thus controls the volume and pressure of gas passing to the burner.

1117. The **regenerative** lamp, or burner, is made in many ways, but the object in every case is to heat the air, or the gas, or both, before the gas is burned. This principle has been applied also to gasoline burners and common petroleum lamps.

The simplest application of the *regenerative* principle is shown in Fig. 395. Two or more small batwing burners are supplied by a pipe which descends close to the flames and which is heated by them. The gas is thus heated before it is burned, and the temperature of the flame is raised accordingly. Even this crude application of the principle of regeneration produces a perceptible increase in the brilliancy of the lights.



FIG. 395.

1118. In the **Wenham** lamp, shown in Fig. 396, both the air and gas are heated before combustion. The burner *a* is an ordinary Argand ring inverted, that is, having the jets of flame upon the bottom end. The flames *b* are turned outwards by a deflector *c*, and they curve over the rounded surface of porcelain rings *d*, thus forming a broad horizontal ring of flame of great

brilliancy. The lamp is closed tightly against the entrance of air below the flame by means of the glass hemisphere *g*.

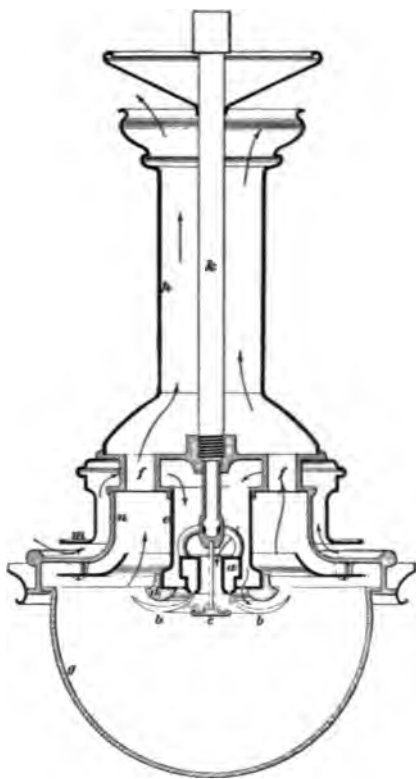


FIG. 396.

The hot products of combustion pass upwards around the tube *c* through a number of tubes *f*, and up the chimney *h*. The gas passing down the tube *k* is highly heated before it reaches the burner. The air required for combustion enters between the cap *m* and the shell *n*, passes between the hot tubes *f*, and thence downwards through the tube *c* to the Argand burner. This construction is said to increase the amount of light given off from three to four times above that produced by good bating burners using the same quantity of gas.

1119. The Lebrun

lamp, shown in Fig. 397, employs a peculiar burner. The lamp is enclosed within a glass globe *g*, and all the air required for combustion is taken in through tubes *a* which connect *d* with the outer atmosphere. The air is heated by passing through these tubes and the central chamber *d*, which are exposed to the upward current of hot products of combustion. The gas burner *k* is an ordinary bulb or rose burner, and the flame is spread out into a convex disk of great brilliancy by means of the current of hot air which flows through the wire-gauze disk *c*. The conical frustum *e* serves to concentrate the hot

gases of combustion upon the sides of the air chamber *d*. The draft is augmented by means of the chimney *h*. The lamp is supported by a pipe *l*, and can be attached to ordinary fixtures by the socket *m*.

1120. The **incandescent** lamp is made in various ways by different inventors, but all of them operate on the same general plan. The **Welsbach** lamp, shown in Fig. 398, is a good representative of the class. The burner is of the ordinary Bunsen variety (see Fig. 400); the gas enters at *a* and the air at *i*. The mixture burns on the top of the wire-gauze cover *b*, producing great heat and but little light. This heat is transformed into light by means of a hollow tubular network *c* which is suspended over and around the burner by a wire support *d*. This

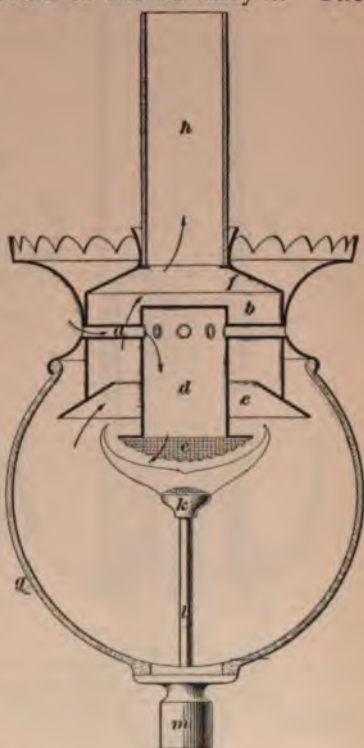


FIG. 397.

network, or **mantle**, is composed of threads of incombustible material, which becomes brilliantly incandescent when highly heated, and thus converts heat into light. The light emitted from the base of the mantle is so brilliant that it is painful to look at directly; therefore, such lamps, if intended for office or domestic use, should be provided with a shade *e* of white or opal glass, to modify the intense glare.

The mantles have been made of many different kinds of materials, notably of platinum wire, but the most successful are now made by saturating a delicate woven cotton fabric with a dense solution of several earthy oxides, such

as magnesia, zirconia, etc.

The mantle is then baked, and finally its temperature is raised high enough to destroy the cotton fibers, leaving the coating of oxides standing as a network of fragile crust. The fragility of the mantles is at the present time the chief drawback to this mode of gas lighting.

This lamp is not limited to the use of illuminating gas. Any variety of combustible gas, oil vapor, or gasoline may be used, by providing a

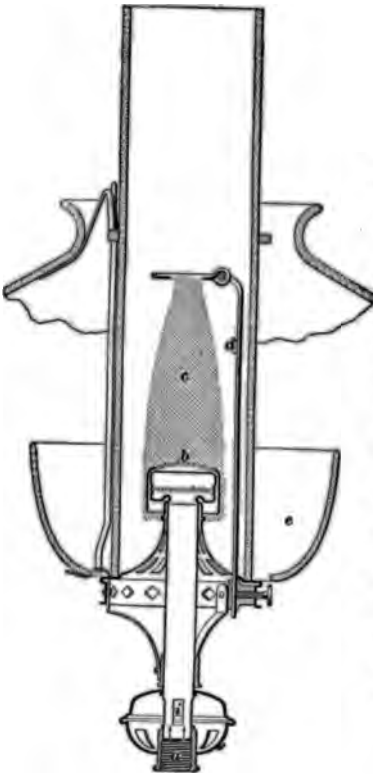


FIG. 398.

suitable burner which is capable of heating the mantle to the proper degree.

Fig. 399 shows an incandescent lamp adapted to burn gasoline. Lamps of similar construction are also made to burn common kerosene.

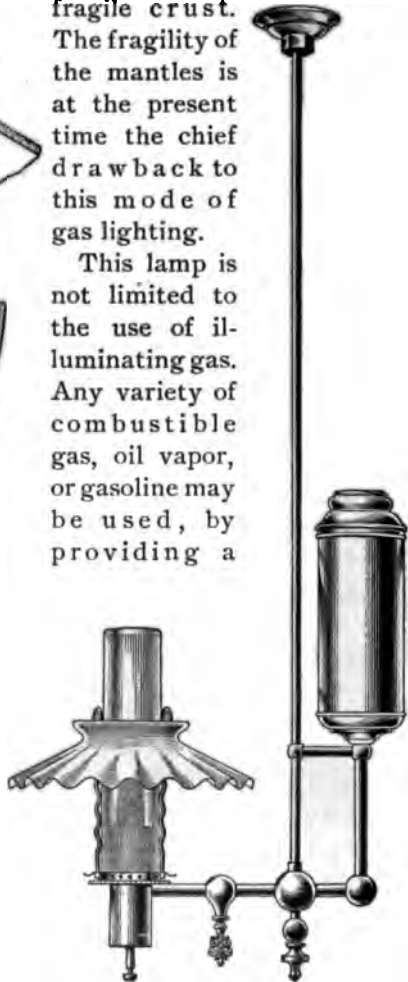


FIG. 399.

BURNERS FOR PRODUCING HEAT.

1121. All burners which are designed to produce *heat* rather than light are constructed to mingle the gas with more or less air before burning. They, therefore, belong to the class known as **atmospheric** burners. There are two varieties of these burners now in common use—the *Bunsen* and the *Fletcher* burner.

1122. The **Bunsen** burner, shown in Fig. 400, is named after its inventor. It consists of a gas tube *a* which projects part way into a larger tube *b*, which is called the mixing tube. Air is admitted through holes *c*, which are closed or regulated by means of the collar, or slide, *d*. The gas issuing from *a* and the streams of air from the holes *c* mingle in the upper part of the tube *b* and form a mixture which will burn over the mouth of the tube. The flame will be quite large and unsteady, and if illuminating gas be burned, it will show a pale blue color with a tendency to green. If the proportion of air is sufficient to make the mixture combustible without the aid of the atmosphere, the flame will flash back with a sharp puff or explosion, and will then burn at the orifice of *a* with an ordinary yellow smoky flame. To prevent this, the slide *d* must be adjusted so as to restrict the supply of air just below the *explosion limit*. If the air supply is much too large, the explosion may be sufficiently violent to extinguish the flame.

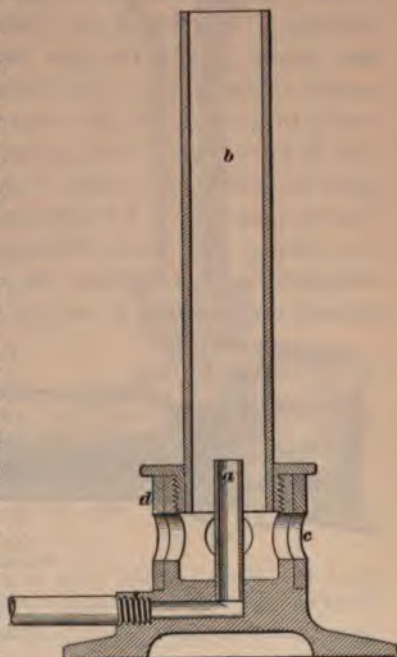


FIG. 400.

1123. The **Fletcher**, or **solid flame**, burner is shown in Fig. 401. That part of the apparatus which serves to mix the gas and air is similar in principle to that used in the Bunsen burner, but the mode of burning the mixture is quite different. The top of the chamber *b* is covered with stout wire gauze *g*, and the gas burns as it issues through the meshes of the gauze. As the gas is already provided with nearly or quite all of the oxygen that it requires for combustion, it burns close to the gauze with a small compact flame of great intensity. The color of the flame, when using ordinary illuminating gas, is a bright green with a few traces of blue. If a larger and more diffused flame is desired, it can be obtained by diminishing the air supply. The flame then spreads out in order to secure the oxygen which is lacking



FIG. 401.

from the atmosphere, and it becomes less intense, appearing more like the flame from a Bunsen burner. When the large flame is used, the central air tube *c* (which passes entirely through the chamber *b*) supplies air to the middle of the flame.

The Fletcher burner is able to develop a higher heat from the gas than the Bunsen burner, because it permits a larger proportion of air to be mixed with the gas. If an attempt is made to burn a mixture having the full proportion of air necessary for combustion, in a Bunsen burner, the flame will blow back, as before explained. The same mixture will, however, burn perfectly in a Fletcher burner, because the flame is prevented from blowing back by the wire gauze *g*. Usually one or more partitions of wire gauze are provided in the interior of the burner, to act as fire checks in case the main gauze should become broken.

1124. The Bunsen burner may be transformed into a Fletcher burner to great advantage by providing it with gauze, as shown at *a* and *b* in Fig. 402. With this arrangement, the flame can be turned down exceedingly low without danger of blowing back or snapping out.

1125. The variety of burner commonly employed in cooking stoves is shown in Fig. 403. The gas and air are mixed within the tube *a*, and the mixture is burned by means of a large number of small flames, which issue from the perforations in the ring *b*. When the burner is to be used for both large and small work, it should be provided with some means of regulating the air supply, so that the mixture of air and gas may always be in the best proportion for economy. In the figure the air inlet is at *d*, and the size of the opening is usually controlled by the slip tube about *a* or *c*.



FIG. 402.

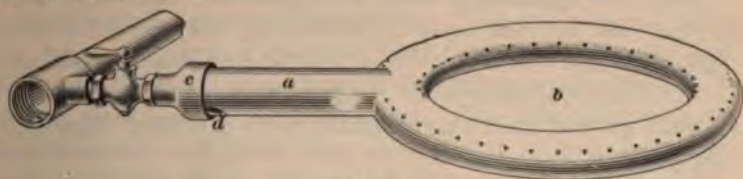


FIG. 403.

When two or more of these burners are used together each ring should have its own mixing tube and gas cock, so that one or all of them may be used as desired.

It is necessary that the gas and air be *thoroughly* mixed before they reach the orifices of the burner. The mixing operation requires a measurable amount of time; therefore,

the mixing chamber must be large enough to afford the gas ample time to mingle with the air properly while passing from the supply pipe to the orifices of the burner.

1126. The air inlet should always be at the lowest part of the mixing tube, or burner, so that none of the gas may escape backwards through it. When there is a possibility of back pressure from any cause, the air should be taken in through a vertical pipe extending some distance below the burner.

For some purposes burners are made to work in an inverted position, that is, with the flame on the under side. They are thus enabled to radiate heat over the top surface of materials exposed below them. This feature is of great value in cooking operations and for certain manufacturing purposes. Of course, the air inlet must then be at a lower level than the bottom of the burner.

The best service can be got from a burner by regulating both the air and gas supply at the same time. For this purpose *compound cocks* are now made which control both inlets simultaneously.

1127. **Vaporizing** burners consist of devices for generating gas from oil by means of heat, being combined with atmospheric burners proportioned to properly burn the gas thus produced.

They are commonly used with gasoline, but other and heavier oils may be used by modifying the vaporizer and burner to suit. Oil vapors have such an abundance of carbon that the quantity of air required to burn them properly is much greater than that required with ordinary illuminating gas.

The liquid is vaporized only as fast as it is used, and the heat required is taken from the flame; usually some of the waste heat is thus utilized. The general mode of construction is to have the oil reservoir elevated above the burner, so that the liquid will flow down to the vaporizer by gravity. The gas produced may be burned in a Bunsen or Fletcher burner, or in a ring burner of the kind shown in Fig. 403.

GAS STOVES FOR HOUSE WARMING.

1128. Fig. 404 shows the interior construction of a common variety of **heating stove**. The gas is burned in an ordinary atmospheric ring burner *a* in the base of the stove. The hot products of combustion are diluted with a quantity of air which enters through the small holes *b*, and their temperature is reduced correspondingly. They pass upwards through the interior of the drum *c* and escape to the chimney through the flue *d*. Baffle plates *e* and *f* are introduced to impede the flow of the hot gases, and to deflect them against the surface of the drum *c* and the central flue *g*. This central flue is very effective heating surface. The air enters at the bottom and becomes highly heated during its passage by contact with the surface of the hot metal.

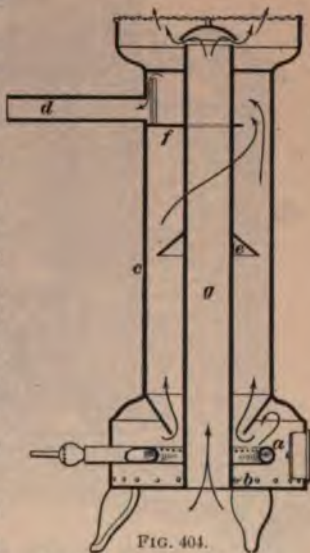


FIG. 404.

1129. Fig. 405 shows a **gas grate** which is designed to occupy an ordinary open fireplace. The back plate is covered with loose bunches of asbestos fibers, and is perforated with a number of fine holes. The gas is mixed with the necessary air in a chamber in the rear, and the mixture passes through the small orifices and burns on the front face of the plate among the loose fibers. The asbestos becomes incandescent, and glows like an open fire of coal, emitting both light and heat. Stoves are also constructed upon the same plan.

1130. A **gas log** is shown in Fig. 406. The log is made of fireclay, and is perforated with a large number of small orifices, through which the mingled gas and air, or the gas only, passes out and burns. The log is hollow, and its interior serves as a chamber in which the gas and air are

mixed before combustion. The heat is radiated directly



FIG. 405.

from the small flames which nearly cover the surface of the log.



FIG. 406.

1131. Fig. 407 shows a **reflecting gas stove.** The gas is burned in a long straight atmospheric burner *a*, which occupies the upper part of the stove. The gas burns in a number of small jets, and the reflector *b*, which occupies the back and lower part of the stove, reflects heat from these flames into the room; being corrugated, it reflects irregularly, and thus scatters the heat. To give a cheerful appearance to the room in which such a heater is placed, the gas is sometimes burned without the addition of air before combustion.



FIG. 407.

1132. The theory upon which many gas heaters are made is that air can be heated by means of radiant heat. This theory is erroneous and deceptive, because radiant heat passes through air without affecting it, except in a very slight degree. It should be borne in mind that *air can be heated only by contact with hot surfaces.*

Nearly all of the heat which is radiated from a stove falls upon the walls or furniture of the room and is expended in warming them. The air in the room is gradually warmed by contact with the surfaces thus heated; some of it is heated by contact with the stove itself, but none of it is warmed by the direct action of the radiant heat.

Thus, the reflecting and radiating heaters which have been described are very effective devices for warming persons, especially those who are cold, wet, or chilly; but they are

quite inferior for the purpose of heating air. The stove shown in Fig. 404 is much better for that purpose, because it has large heating surfaces over which the air may travel. The prime requisite of an air-heating apparatus is an abundance of hot surfaces.

1133. No gas stove or heater should be permitted to discharge its products of combustion into the air of the room, because it will vitiate the air with great rapidity. Every heater should be connected by a pipe to a chimney, or should have a hood over it which should have a free discharge into the outer atmosphere.

WATER HEATERS.

1134. There are two varieties of heaters for heating water by gas now on the market. One is designed to be attached to the ordinary kitchen boiler to furnish a moderate steady supply of hot water, sufficient to meet the usual demand. They are made in several ways. A common method is to employ a vertical cylindrical coil of copper pipe, through which the water may pass, and to place an atmospheric burner at the base of the coil, passing the hot products of combustion up the interior of the coil and between its convolutions.

A heater of this variety, suited to a 50 or 60-gallon boiler, usually contains about 35 lineal feet of $\frac{3}{4}$ -inch copper tubing, and the burner is made to consume from 20 to 25 cubic feet of ordinary illuminating gas per hour. This variety of heater is apt to produce a disagreeable drip of water from the coil when at work, the drip being often mistaken for leakage. It is one of the products of combustion of gas (see Art. **1105**), and its presence in the liquid form shows that some part of the coil is below boiling temperature, and thus acting as a condenser. This same trouble applies to heaters in which the hot products of combustion flow through the inside of tubes or coils.

1135. Another variety of water heaters, called **quick**, or **instantaneous**, heaters, is used for heating small quan-

tities of water to the boiling point in the least possible time. The heater is usually placed in the kitchen over the sink, or at the bath-tub or bowl where the hot water is required.

Fig. 408 shows the interior construction of one of the best of these devices. The water is heated in the coiled pipe *a*. It enters at the bottom, passes gradually upwards and is discharged at the top through a faucet, not shown in the figure. The burner *b* is an ordinary Bunsen burner, and the chimney *c* is made just large enough to admit the air necessary for perfect combustion. The pipe coil is surrounded by a casing of firebrick *d* and *e*, which prevents loss of heat. The hottest part of the flame plays upon the upper part of the coil, and the hot gases pass between its convolutions and escape downwards, as shown by the arrows, passing out through holes in the base ring *f*.

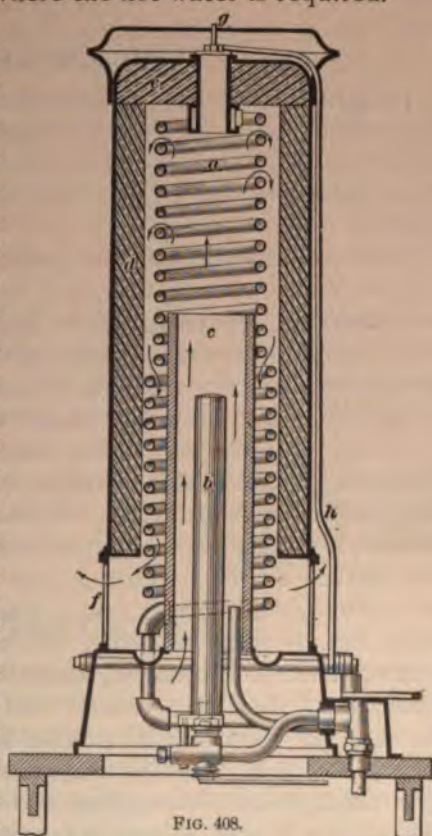


FIG. 408.

The heat is thus applied to the coil in a very effective manner, and a moderate stream of hot water can be maintained continuously.

In heaters of this kind there is danger that an explosive mixture of gas will remain in the top of the fire chamber when the burner is shut off, and blow badly when a light is applied. This is prevented by means of a damper *g*,

which is connected by a rod *h* to the handle of the gas valve, so that it will remain open as long as the gas is shut off.

FIRE CHECKS.

1136. In burning explosive mixtures of air and gas, it is necessary to employ some device for the purpose of confining the flame to a certain place, and thus prevent it from spreading backwards into the mixing chamber or reservoir.

Before combustion can take place, the temperature of the gaseous mixture must be raised to a certain degree, called the **point of ignition**. Now, if the mixture can be separated from the flame by some kind of a screen *which will not become heated to the point of ignition*, it is evident that it can not be set on fire by contact with the screen.

The device most frequently employed as a fire check is a partition of *wire gauze*, through which the mixture of air and gas is forced to pass. As the gas passes through the meshes of the gauze, it is carried some little distance beyond the surface before it burns; consequently, the flame does not actually touch the gauze. The heat radiated from the flame rapidly heats the wires, and would soon raise them to incandescence if no cooling influence were brought to bear upon them. But the stream of cold air and gas which passes through the meshes absorbs the heat from the wires and keeps them at a moderate temperature. If there is no current through the wire gauze, and if fire be maintained on one side of it and an explosive mixture on the other, then the safety will depend entirely upon the rapidity with which the cold mixture can absorb and carry off the heat from the wires. Usually the conductive power of the air and gas is not sufficient to keep the temperature of the wires below the point of ignition for any considerable length of time, and an explosion consequently results.

An explosion on one side of a gauze partition will not set fire to an explosive mixture on the opposite side (unless the force of the explosion bursts a hole in the gauze and thus

permits fire to pass), because the temperature of the flame will fall rapidly, and it will die out before the gauze becomes heated to the point of ignition.

Other devices are sometimes used for fire checks. The explosive mixture may be passed through metal tubes having a small bore and considerable length, or it may be passed through narrow passages between flat metal plates: the essential point is that the heat which is received from the flame shall be conducted away or dissipated so rapidly that the temperature of the metal can not be raised to the point of ignition at the end where the mixture enters.

The mesh and the size of the wire composing the gauze are matters of great importance. The wire should be of brass or copper, woven with twenty-eight or more lines to the inch, the gauze having not less than 784 meshes to the square inch.

Gauze made of iron or tinned wire is very liable to be spoiled by rust holes, and the metal does not conduct the heat away fast enough. It should not be used for fire checks.

FIXTURES.

1137. The term **fixture** is applied to the apparatus which supports the gas burners and serves to connect them to the supply pipes. They are divided into three general classes: **brackets**, or **side lights**, which project from the walls; **pendants**, or **chandeliers**, which hang from the ceiling, and **pillar lights**, which stand upon a base, such as a mantel, a table, or a newel post.

Brackets made without joints are called *stiff* brackets, and those having flexible joints are called *swing* brackets.

All fixtures which hang from the ceiling may properly be called pendants; but, as commonly applied, this name is restricted to fixtures carrying one or two lights, and which are of plain construction. If the number of lights is greater, or the construction is decidedly ornamental, the term *chandelier* is used instead. This name is applied to the fixture

without regard to the variety of lights which it carries, whether candles, kerosene lamps, gas burners, or electric lamps. The terms *gasolier* and *electrolier* have been devised to distinguish a chandelier bearing gas lights from one carrying electric lamps, but these words are objectionable—they are formed without regard to the laws of language—and their use is not recommended.

There is another class of fixtures called *sun lights* and constructed in a great variety of ways. They are used chiefly to produce a great amount of light near the top or ceiling of large audience rooms, and also to furnish copious illumination for show windows, etc.

1138. A **sun light** consists of a large group of small gas burners which are attached directly to the supply pipe and a reflector which is adapted to throw the light downwards as much as possible. The group is made up in a circle, or sometimes in a rectangle or in parallel lines. The burners are usually set so closely together that when one is lighted it will ignite the adjoining jets, and thus light up the whole group. The flames, however, should not touch each other when burning.

Ornamental fixtures are usually built over a frame or skeleton of plain brass or iron tubing. The ornamental part consists of thin tubes, or shells, of brass, which are slipped over the main tubing, and are bound in place by screwing the various fittings tightly together.

1139. The most important part of any fixture, however, is the **key**, or cock, by which the gas is turned on or off. The safety of the inmates of the rooms from poisoning or suffocation, or from injury by explosion of gas, requires that the key of every fixture be properly constructed, and also that it be properly adjusted. If a key is loose in its socket it is very liable to be opened accidentally, or to be reopened unintentionally in the act of removing the fingers after closing it. A loose key is such a dangerous thing that it should not be permitted to remain under any circumstances.

The proper construction of a key is shown in Fig. 409. The plug *a* should be tapered, and should be ground into its seat until it has a perfect bearing throughout the whole length of the socket. It should be held in place by means of a screw *c* and a washer *b*. The washer should have a central hole with one or two straight sides, as at *d*, and it should fit over the flat-sided end of the plug without looseness or play, so that when the plug turns, the washer will turn with it. If there is any play at this point, it will operate to loosen the screw *c*, and thus spoil the tightness of the key. It is a very common mistake to make the dimensions of the washer and screw too small, causing the washer to quickly wear loose when the screw is properly tightened up. The head of the screw should always be made large enough to afford a good hold for a screwdriver. Keys having small thin washers, or screws with small shallow nicks, should be rejected. There should always be some clearance under the washer and under the screw head, so that when the screw is tightened up they will never come to a bearing on the end of a plug.

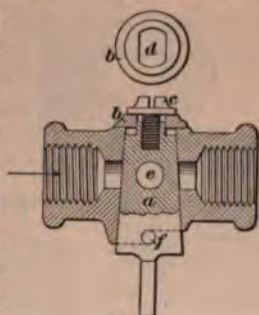


FIG. 409.

1140. An important detail of a key is the **stop pin** *f*. This pin projects from the side of the plug and engages shoulders cut on the body of the socket; this limits the motion of the plug to one-half turn, always stopping the plug when the key is fully closed. This pin should be strongly made, so that it can not be easily broken.

A key which has no stop pin is dangerous, since it is quite likely to be left open a little when it is believed to be closed. Such a key, when discovered, should not be permitted to remain in use, but should immediately be repaired or replaced.

The diameter of the hole *e* should never exceed one-third the diameter of the plug at that point. If the hole is made

larger, the bearing surfaces are so reduced that the key is likely to become leaky in a short time.

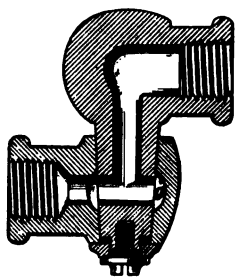


FIG. 410.

The plug should be lubricated with mutton tallow, the excess of tallow being carefully removed from the passages for gas.

1141. The construction of **swivel joints** is shown in Figs. 410 and 411. The mode of securing the plugs in the sockets is the same as in Fig. 409. Each socket is provided with a groove *g*,

which permits the gas to pass freely into the bore of the plug in all positions. Fig. 410 shows an ordinary **single swivel joint**, and Fig. 411 shows the arrangement of a **double swivel, or universal, joint**. The plug *h*, Fig. 411, turns in a socket *k*, formed in the head of the plug *m*, which also revolves in the socket *l*. The pipe *n* can thus swing around the axis of either plug, or both at the same time.

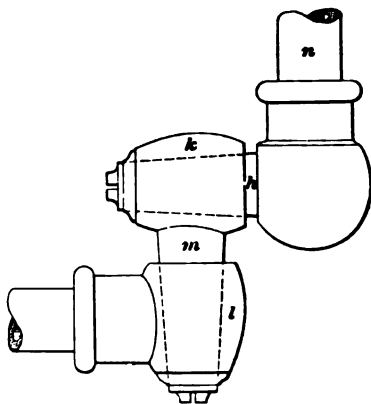


FIG. 411.

This mode of construction is not suitable for apparatus which requires a large supply of gas, because the dimensions become so great as to be clumsy.

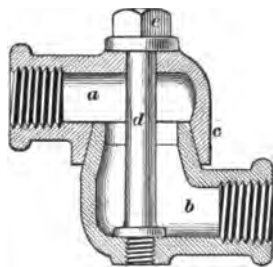


FIG. 412.

When the full capacity of the pipe is required to carry the desired amount of gas, the swivels may be constructed substantially as shown in Fig. 412. This is called a **full-bore swivel**. The sections *a* and *b* are fitted together with a conical joint *c*, which permits complete rotation. The joint is

tightened by means of the bolt *d* and nut *e*, and if it becomes leaky at any time, it can be readily reground. The passageway for gas is equal to or greater than the full area of the pipe at all points; therefore, it offers very little obstruction to the flow.

1142. Fig. 413 shows the construction of a **ball joint**, which permits the tube to swing to a limited extent in any direction, and also to turn on its own axis. The tube *b* is attached to a ball *c*, which is confined in a socket *d* by means of a screw-cap *e*. Packing material, usually a cup leather, is employed to make the connection from *a* to *b* gas-tight. The swing of the tube is limited by the size of the hole in the cap *e*. This class of a joint is often used at the top of swinging chandeliers, *a* being the iron pipe drop piece extending through the ceiling.

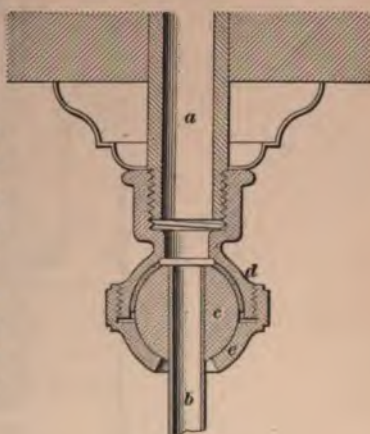


FIG. 413.

1143. An **extension**, or **telescopic**, chandelier is shown in Fig. 414. The fixture is provided with two tubes, an inner one *a*, which serves to conduct gas to the burners, and an outer one *b*, which has a cup *c* at the top end. The space between the tubes *a* and *b* is filled with liquid, and the supply pipe *d* dips below its surface at all times, thus preventing the gas from escaping. The pendant is held up by chains *e* and weights *f*, and it can be raised or lowered as desired. The chains are provided with stops to prevent the pendant from being lowered so far that the liquid may uncover the end of the pipe *d*. Instead of the chains and weights, coiled springs (like sash balances) are frequently used to sustain the fixture. The liquid may be either oil, glycerine, or mercury; water is unsuitable because it evaporates rapidly.

1144. This variety was formerly much in use, but in recent years it has given place to that shown in Fig. 415. The liquid seal is replaced by a stuffing-box *g*, which is attached to the top of the sliding tube *k*, and which slides gas-tight over the supply tube *h*. The outer tube *m* is provided with a collar *n*, which guides the draw-tube *k* and

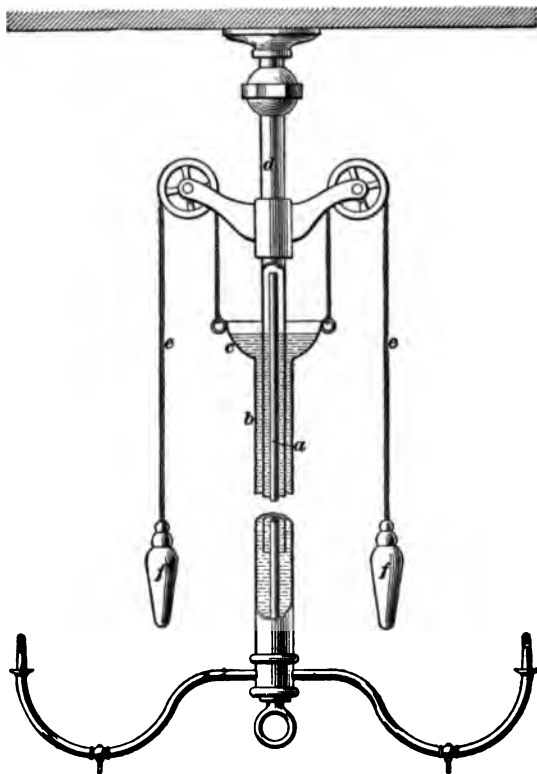


FIG. 414.

prevents dust from entering the interior and settling upon the surface of the tube *h*. The lubrication of the tube and stuffing-box can thus be maintained for a long time. As the tube *h* has only to supply gas, it can be made quite small in diameter. The devices used for balancing or sustaining this fixture in position are of many kinds. One of

the best of these is a friction clutch which permits the draw-tube to slide upwards without resistance, but which grips it and prevents it from moving downwards, except when pulled down by force.

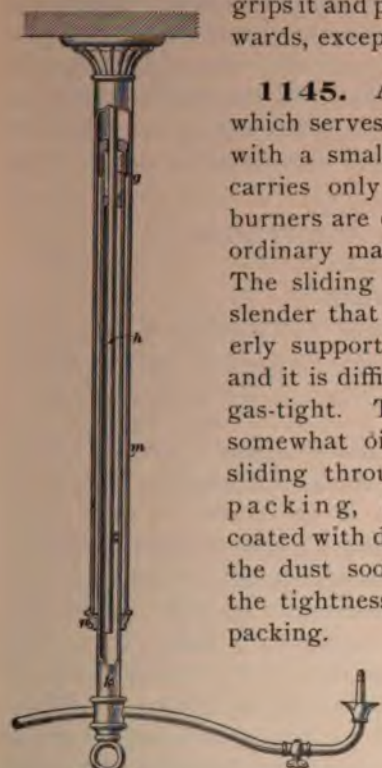


FIG. 415.

1145. Another variety of chandelier which serves a similar purpose is provided with a small sliding tube which usually carries only one burner. All the other burners are carried on rigid arms in the ordinary manner and are not adjustable. The sliding tube, however, is usually so slender that it lacks the strength to properly support the weight of a good shade, and it is difficult to keep the stuffing-box gas-tight. The surface of the tube, being somewhat oily after sliding through the packing, becomes coated with dust, and the dust soon spoils the tightness of the packing.

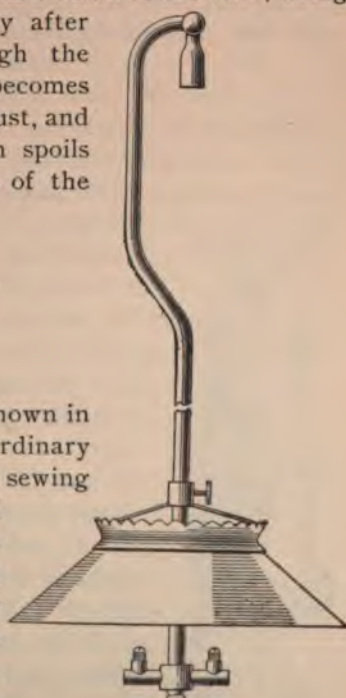


FIG. 416.

1146. The **drop light**, shown in Fig. 416, is to be preferred for ordinary uses, such as for reading or sewing tables. It consists of a tube of suitable length having a burner and shade at its lower end and a socket, or cap, at its upper end; this socket is lined with rubber and is adapted to fit gas-tight over the body of an

ordinary burner. The socket should always be quite close to the tube, so that it can be passed up through an ordinary globe ring or holder. The tube should be offset so that the center of gravity of the shade, etc., will come directly under the socket without tending to bend the burner to which it is attached. The tip should be removed from the burner before attaching the socket to it. Many chandeliers are provided with a small stiff bracket, made especially for use on drop lights.

DETAILS OF FIXTURES.

IGNITERS.

1147. Igniters are devices for lighting gas-burners either singly or in groups, and are designed to save the time and labor which would be required to light them by hand.

1148. A self-lighting gas-burner is shown in Fig. 417. The key is so made that the gas can never be entirely shut off, and when it is turned to extinguish the light, a small amount of gas is still allowed to pass, enough to maintain a small **peep** of flame at the tip of the burner. In order to protect this little flame from extinction by drafts of air, it is enclosed by a cap, or globe, *g*. When the burner is in full operation, the globe drops down below the flame to the position shown; but when the lever *b* is reversed to shut off the gas, the link *d* operates to raise the globe above the top of the burner, thus shielding the little flame from accidental extinction. The lower end *a* is a socket threaded and soldered to fit the ordinary fixture. The fixture to which this burner is attached must be provided with a key, as usual, so that the burner may be entirely extinguished when desired.



FIG. 417.

1149. Sun lights and other large groups or clusters of burners are usually lighted in a similar manner. When the cluster is extinguished, one small tip is left burning, and this serves to relight the whole group when the gas is again turned on. This small burner is commonly called a **pilot light**, and it is supplied with gas by a separate pipe. The supply of gas to all the other burners is controlled by a single cock, so that they may be turned down simultaneously, and may be extinguished or promptly relighted whenever desired.

There are also a large number of igniting devices which operate by means of electricity. Two methods are in use: in one, an electric spark is caused to flash through the stream of gas issuing from each burner, thus igniting it; in the other, a small piece of platinum wire is heated to incandescence near the tip of each burner, the electricity being turned on after the gas issues from the burners, and shut off as soon as the lights appear.

1150. Safety burners are designed to automatically close a valve and shut off the gas when the flame is extinguished. A great many devices of this kind have been patented, but few of them will operate with sufficient certainty to be worthy of confidence. Nearly all of them employ bars of metal or other substances which are expanded by the heat of the flame, and while in that condition hold the gas valve open. When the flame goes out, the expanding body contracts by cooling and permits the valve to close.

One of the most simple and probably the best automatic safety burner is that shown in Fig. 418. It is simply an ordinary batwing or other form of a burner tip fitted with a disk *a* and a platinum coiled spring *b*. When the spring is cold it draws *a* to its seat and shuts off the gas. When it is heated the spring ex-

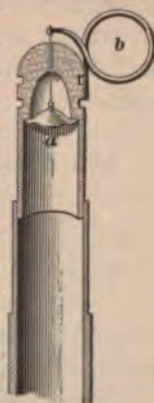


FIG. 418.

pands and pushes down the valve, thus opening a passage

for the flow of gas. The edge of the gas flame touches the spring and keeps it heated, but the moment the gas is extinguished, whether shut off at the gas-cock or blown out by accident or ignorance, the valve will quickly take its seat. These burners are particularly valuable for hotel service, because many people (those accustomed to the use of kerosene lamps, etc.) do not even know how to shut off a gas flame, and it is not uncommon to hear of country people being suffocated in city hotels. They are inclined to forget themselves, or perhaps, are too proud to ask for information, and, consequently, "blow out the gas" and go to bed.

Another great need for safety burners arises from the fact that, when the gas supply is interrupted or shut off, every burner is extinguished, but the keys are not closed. When the gas comes on again, it streams out of each open burner, and in many instances does great damage by causing explosions or by suffocating the inmates of the building.

GLOBES.

1151. The primary object of enclosing a gas-burner within a globe is to protect the flame from interference by drafts of air. A globe, however, acts as a chimney and causes a strong upward current of air to flow through it. If the dimensions of the globe are not suited to the size of the flame, the air current will cause the flame to flicker badly, and the globe then becomes a detriment instead of an advantage.

The opening at the top or bottom of a globe should never be less than 4 inches in diameter for an ordinary 5-foot burner, and a larger size is still better.

1152. Globes are often required to serve the purposes of shades, to modify and soften the light. For this purpose the outer surface of the glass is etched, or **ground**, or colored glass is employed. These globes obstruct the light, the loss being about as follows :

Ground glass globes.....	10 to 30 per cent.
Opal glass globes.....	30 to 40 " "
Colored glass globes.....	40 to 60 " "

Globes of clear glass obstruct the light somewhat; but, if the globe is properly proportioned, the intensity of the light will be increased by the draft which it creates, and the increase of light will counterbalance the loss by obstruction.

SHADES.

1153. Shades are commonly used to prevent the light from passing upwards, and to reflect a considerable part of it downwards. It is, therefore, desirable that the under side of the shade should have a good reflecting surface. For table and desk lights, the shades should be made of opaque material, and should act as reflectors only.

The color of globes and shades is a matter of some importance. If translucent shades are used, they should be either white or opal. Red, green, and blue shades should not be used, because of the bad effect of the colored light upon the eyes, red light, especially, being very tiresome to sensitive persons.

The central opening in the top of the ordinary shades permits a considerable portion of the light to pass upwards to the ceiling. When it is desired to prevent this, top reflectors may be used to intercept the light and throw it downwards, as shown at *a* in Fig. 419.



FIG. 419.

SHIELDS.

1154. The distance between an ordinary gas-burner and the ceiling should be not less than three feet. If a less distance is unavoidable, the ceiling should be protected by a metal shield to prevent it from being scorched or

burned. The shield should be separated from the ceiling by a clear space of at least two inches, to permit air to circulate between them. Even when a shield is provided, a gas flame should not be permitted at a distance less than eighteen inches below the ceiling.

If a gas flame is liable to come into accidental contact with inflammable materials, such as curtains or drapery blown by the wind, or hay and straw in stables, etc., it should be provided with a glass globe, and should also be enclosed within a stout wire cage at least ten inches in diameter. The only safe way to determine the proper size of the wire guard is to test it by holding pieces of cloth or paper against it. If the material can be set on fire, the guard should be made larger.

DISCOLORATION OF CEILINGS.

1155. Each gas flame causes an upward current of hot air, which ascends until it reaches the ceiling. This produces a circulation of the air within the room, and particles of dust in the current will be carried to the ceiling at a point directly over the burner. Consequently that part of the ceiling soon becomes discolored by the dust which adheres to it. The discoloration is usually charged to smoke from the gas, but it is mostly due to the stream of dust. If the gas does actually give off smoke, it will aggravate the trouble, but that can be easily remedied by providing a proper burner.

The trouble may be mitigated, although not wholly cured, by using a deflector, as at *a* in Fig. 419, or by hanging an ordinary smoke-bell over the flame. By spreading out the current, its velocity is checked, the amount of dust which strikes the ceiling within a given area is thus reduced, and the discoloration is lessened.

The only effectual method of preventing the discoloration of walls and ceilings in this manner is to intercept the current of hot air arising from each burner, and to conduct it to a chimney or ventilating flue, by means of a hood suspended over each flame, or set of flames, and suitable pipe connections. This plan is valuable for another reason :

Not only are the products of combustion removed from the room, but a considerable amount of air is carried along also, thus aiding ventilation. The hot gas which is discharged into the ventilating flue raises the temperature therein, and thus increases the draft and improves the operation of the flue.

LOCATING FIXTURES.

1156. The chief considerations which govern the location of gas fixtures are: first, that they shall light the rooms to good advantage, and, second, that they shall cause no danger from fire.

1157. In lighting **bedrooms** the fixtures should be located so that the bed, wardrobe, dressing case, mirror, etc., may be placed in desirable positions without interfering with the light. The positions of the closets should be noted, and, if practicable, the light should be arranged to shine into them, so that the contents may be easily seen.

1158. **Dressing mirrors** should be provided with two stiff bracket lights, one at each side. They should be placed as high as they can conveniently be reached, in order to properly illuminate the head and shoulders of the person using the mirror.

1159. In **bath rooms** the lights should be set high, so that a person will not be liable to strike them in taking off or putting on clothing. A light should not be located *over* a bath-tub or a wash bowl, or anywhere near them, because of the liability to accident.

1160. **Stairways** should be provided with a light at the top, whether there is one at the bottom or not. A light on the newel post alone is not sufficient to properly illuminate the steps. People having defective sight are especially liable to accident on stairways, and the light should be arranged so as to avoid all shadows which might prove deceptive.

1161. A **kitchen** or **laundry** should be lighted by pendants whenever practicable. If side lights must be used, they should not be placed over the sink or near enough to it to be liable to be struck or be splashed with water. The best place for a side light is usually over the pastry table.

A side light should not be placed over a set of tubs if it can be avoided. A better place is at the head of the ironing table.

The stairway leading from the kitchen to the basement or cellar should be lighted by a burner which is located some distance away from the foot of the stairs. If the light is near the foot of the stairs, it is very apt to be struck when large articles are carried past it.

1162. **Hallways** are best lighted by a pendant; if a side light is used, it should be placed where it will not interfere with the coat rack, or mirror, or other hall furniture.

A pendant in a hallway or vestibule should be set so high that the globes will not be liable to be knocked off by a person who is putting on an overcoat, etc.

1163. **Chandellers** should be hung from the center of the ceiling as nearly as practicable. If several side lights are used in the same room, they should be placed at the same height.

1164. **Swing brackets** should not be used for lighting hallways, stairs, vestibules, or other passageways, because of the danger from fire. The light is very liable to be swung too close to the wall, and to be overlooked until the building is set on fire. Swing brackets are always a source of danger when they are located within reach of woodwork or drapery, and, therefore, are not to be recommended for general use. It is preferable, in most cases, to use instead two single lights on stiff brackets, or else a bracket having two or more rigid arms with fixed lights.

A gas fixture should never be placed in a **closet** or other very small room, if there is any chance that the door may be closed and the light left burning. If that should happen,

the temperature would rise rapidly, and there would be great danger of setting fire to any combustible material that might be in the room.

Care should be taken in locating side lights, to make sure that wooden doors can not be swung back against them, and be scorched or set on fire. Lights should not be placed where they may be blown out by strong drafts of air, or by the sudden slamming of a door. A gas-burner when extinguished, with a full head of gas on, is very dangerous.

1165. Hot-air registers in the floor or wall should be carefully avoided in locating gas fixtures. If a light is over or near a register, it will flicker incessantly, and will be a great annoyance.

1166. The proper **height** of gas lights above the floor depends somewhat upon circumstances. In ordinary dwellings having a ceiling 9 feet high or more, side lights should be placed from $5\frac{1}{2}$ to 6 feet high. Pendants may be hung from $6\frac{1}{2}$ to 7 feet from the floor. If the rooms are large and high, the lights of chandeliers may be placed at a height of 7 to 8 feet, or even more. Of course, all lights above 7 feet high will require the assistance of a torch or step ladder to light them.

Side lights in hallways and vestibules of churches and similar buildings should be placed at a height of at least 7 feet.

Low lights should be avoided, because they are tiresome to the eyes. If they must be used, they should be provided with opaque shades, as before mentioned.

COMPLAINTS AND REMEDIES.

1167. The troubles which gas-fitters are commonly called upon to remedy are of several varieties.

Leaks are liable to occur in any part of the pipe system, or in the fixtures. Sometimes strong odors of gas will prevail even when a careful search fails to locate a leak. At times the gas lights will jump and flicker so badly that

they are almost useless, and in extremely cold weather the gas supply sometimes appears to freeze up.

The atmospheric burners used in cooking apparatus will often blow back, or smoke, in a most exasperating manner. Heating stoves, gas logs, etc., will blow back and burn with a yellow flame at the gas inlet, and sometimes will puff with sufficient violence to extinguish the flame and let the gas pour into the room unchecked.

Occasionally, a dissatisfied householder will complain that his gas bills are larger than at the same season any year before, and will request the gas man to "come and see what he can find that is wrong."

LEAKS.

1168. Repairing gas leaks is a dangerous business, because any mixture of common illuminating gas with air in the proportion of 13 parts of air to 1 of gas will explode if it comes in contact with fire of any kind. If the explosive mixture be richer in gas, it will explode with proportionately greater violence.

Before entering a room which smells strongly of gas, all lights must be extinguished, and lighted cigars or tobacco pipes must be left behind. All matches should be laid aside, because the workman is liable, in a moment of thoughtlessness, to strike a light to "see where he is," and thus produce an explosion.

If the place is very dark, and a light is required, then a coal miner's **safety lamp** should be used. Even these lamps must be used with caution. The necessary instructions for handling them are furnished with the lamps.

Occasionally there is a risk of being suffocated or overcome by the gas, and the gas-fitter should always have an assistant within sight who can help him out in case of accident. If he begins to feel dazed or *queer* while breathing the contaminated air, he should drop to the floor and make his way out on hands and knees. The air near the floor is likely to be nearly free of gas, thus giving him a chance to breathe.

1169. In beginning a search for a leak, the first thing to do is to shut off the gas at the meter, or, if that can not be reached safely, it may be shut off at the curb. Then the windows and doors should be opened, and every effort made to free the premises from the presence and odor of gas.

All places which can not be readily ventilated, such as the upper parts of closets, small hallways, space under stairways, etc., should be thoroughly fanned out, driving out the gas into the air currents which will carry it off. The space between the floors may be filled with gas, and sometimes it is necessary to make openings and circulate air through them to clear out the gas.

If the apparent proportion of gas in the air does not plainly diminish when the supply is shut off at the meter, then the leak is probably in the service pipe outside the building. It may be that the leak is in the main, and that the escaping gas follows the service pipe and enters the premises through the pipe hole in the cellar wall. In pervious or *made* ground, the gas from a leak in the street will sometimes follow a water pipe into the cellar. This is most likely to occur when the ground is frozen hard, because then the gas escaping under the street can not rise up through the ground and escape from the surface.

After the premises are cleared of the odor, the gas should again be turned on at the meter.

1170. Ordinarily the leak can be located approximately by the odor of the gas which again escapes from it. If there is no plain indication of its source, then a systematic search must be made. The first point to be examined for leakage, in the system of house pipes, is at the meter. Leaks may occur in the meter casing or around the glass cover over the register dials. If a defect is found here, the meter should be removed and a sound one put in its place. A small leak may be stopped temporarily by the use of hard soap as a cement, but this can not be depended upon to remain tight for more than a few days. The meter

connections should then be examined, and, if the couplings are found to be leaking, they should be supplied with new washers. The gas fixtures should next be examined, taking care to ascertain positively the tightness of every cock or key. Leaks may occur at the swing joints and at the base of the burners, but these will be perceptible only when the fixture is in use. Chandeliers and pendants should be examined at the connection to the drop nipple overhead, and at the ball joint, if there be one.

All stuffing-boxes on sliding or extension fixtures should be closely examined. Leaks may also be looked for at either end of the nipple at brackets or side lights.

If no leak is found at the meter or fixtures, then the defect is evidently in the pipes or fittings, and the only practicable method of finding it is to *prove* the pipe system, as directed in the section on testing. (See Arts. 1101 to 1103.)

The use of matches to detect small leaks of gas is a dangerous practice; they should never be used in any place where there is a chance for escaping gas to accumulate and mix with air. Smearing the pipe with thick soapsuds is more certain to reveal small leaks, and is free from danger.

If no leak can be found upon the premises, and the odor of gas still exists, it is probable that the leak is in some other pipe system, and that the gas is conducted into the premises through some unsuspected channel, such as accidental passageways between floor-beams, rat holes, loose spaces around water pipes, etc.

FLICKERING LIGHTS.

1171. The flickering and jumping of gas lights are caused by the presence of water in the pipes. The liquid accumulates in sags and low places, and fills the bore of the pipe, forcing the gas through it in a series of bubbles. As each bubble escapes the water is agitated, and the lights jump in response to the momentary fluctuation of pressure. This trouble can be remedied by emptying the drip cups and taking care to thoroughly drain all parts of the pipe system. Some-

times the deposit of water will be found in the fixture instead of in the supply pipes, especially if it be a pendant or chandelier.

A similar effect is caused by a wet meter which is *drowned*, or flooded, by too much water. In this case the trouble may be overcome by drawing off the excess of water.

Dry meters are seldom troubled with the water condensed in the pipes; they are usually provided with *trap screws*, so that the water can be easily removed when necessary.

The apparent freezing up or choking of the gas supply in extremely cold weather is due to the exposure of the pipe at some point to a draft of very cold air or to a freezing wind, the consequences of which are described in Art. 1100.

CHOKAGE.

1172. When gas pipes become choked, they may be cleared in most cases by blowing them out with compressed air.

An ordinary air pump is used to compress air into a strong storage tank, and when a sufficient pressure has been accumulated, the tank is connected to the choked pipe, and the air is discharged into it as suddenly as possible, thus blowing out all obstructions before it.

1173. A **service cleaner** is shown in Fig. 420.

The bulged part, or base, forms an air chamber, and is surmounted by a common hand pump, which forces air into the chamber. The lever handle cock near the bottom connects to the gas-pipe system. The duty of the air chamber is simply to store up air under pressure, so that when the stop-cock is opened



FIG. 420.

suddenly a large volume of air will instantly blow through the pipes.

When a service pipe is choked or trapped with water, it is disconnected from the meter, and air is quickly forced through towards the main. If the pipes in the building are choked, the gas fixtures affected by the choke are taken down, and air is rapidly forced through their supply pipes, so that the obstructions will be blown out at the open ends of the drops.

SMOKY LIGHTS.

1174. The smoking of ordinary gas flames may be due to defects in the burner, or to excessively rich gas. Smoke is produced only when the supply of air is too small to burn the carbon in the gas.

If the tip fails to spread the flame sufficiently to secure the necessary oxygen for good combustion, the burner will smoke.

The defect may be in the tip, or it may be that the pressure is reduced too low by a check in the interior of the burner. The proper remedy is to provide a new tip having a thin, clean slit, and if that does not properly spread the flame, then the check should be readjusted or removed so as to increase the pressure.

If the gas smokes because it is extra rich, the trouble may be remedied by providing the burner with a glass globe or by using a burner having a chimney, thus securing a larger supply of air.

STOVE BURNERS, ETC.

1175. The atmospheric burners used in cooking stoves, etc., seldom give any trouble if they are properly proportioned and adjusted. If the mixing tube is too small, the supply of air is apt to be insufficient, and to be imperfectly mixed with gas, thus causing the burner to smoke.

These burners frequently become foul, and sometimes become clogged with burnt grease, etc. Each hole, or jet, should be cleaned by inserting a wire, and the mixing tube should be inspected and cleared of all lint and dirt.

The trouble with gas grates, gas logs, and similiar gas heaters is that they will sometimes blow and *snap out* or extinguish the flame, when the pressure in the supply pipe becomes unusually low. The reason for this is that the air supply remains nearly unchanged, while the gas supply diminishes; thus the relative proportions are altered until the mixture becomes explosive. This trouble may be remedied by adjusting the burner and air inlet to work properly at a certain minimum pressure, which is assumed to be the lowest that will occur, and using a pressure reducer, or governor, to maintain the supply of gas to the heater at that pressure.

GENERAL IMPROVEMENT.

1176. When the gas-fitter is requested to inspect the gas-lighting apparatus in a dwelling or other premises and to "fix up" everything that appears to require improvement, in the hope of reducing the consumer's gas bills, he should begin by ascertaining if the various burners are supplied with gas at a sufficient pressure. This can be done by lighting all the burners that are ever in use at the same time, including all cooking and heating burners, if any. The appearance of the flames will show whether the supply pipes are large enough; if still in doubt, the water gauge should be applied.

If the pressure appears to be too low, it may be due to the fact that there is a pressure reducer, or governor, at the meter which is improperly adjusted. Sometimes these governors become fouled, causing considerable resistance to the passage of gas. By opening the governor valve to its full width, or by removing the governor temporarily, it can be quickly ascertained whether the lack of pressure is due to the smallness of the pipes or to the resistance of the governor. Sometimes the trouble is due to a defective meter. The condition of the meter can be judged by applying two water gauges, one upon each side of it, as previously explained.

1177. Each burner should be supplied with a volumetric regulator. These will save so much more gas than a

pressure reducer can that it is generally advisable to put them on.

If any atmospheric burners are used for cooking and heating purposes, the governor at the meter should be adjusted to give the pressure most suitable for their use, leaving the volumetric regulators to take care of the illuminating burners.

If there is no governor on the system, the pipes leading to the stoves should be supplied with one. The burners should be closely inspected and cleaned. Each one should be provided with a compound cock which adjusts the air and gas inlets at the same time, and the cock should be so adjusted that the proportions of air and gas are at all times the highest that can be used without snapping back.

Close attention should then be given to the condition of the illuminating burners. The flames should be as large as practicable, and should be perfectly steady, without flickering or hissing noises. The outline of the flame should be smooth and free from wavering tongues or deep notches. The color should be as near white as practicable. If the flame is yellow or dull, suggesting smokiness, it shows that it is not spread out sufficiently. The tip should be replaced with a new one having a thinner slit.

The question of illumination should also receive attention.

Frequently several small burners are used to light a room, when one or two large burners would give more light, with a smaller consumption of gas.

Gas lights which are used only a few minutes at a time and are turned down during the intervals, as in bathrooms, water-closets, cellar stairways, etc., are usually very wasteful of gas, and a saving can be made by employing self-lighting burners in all such places.

It is to the interest of the consumer that all the lighting and heating burners upon his premises be thoroughly inspected and put in good order at least once every year. When the inspection is made annually, it requires but little time, and the cost is small compared with the saving that will usually be made in the gas bill.

GAS MAKING.

THE DIFFERENT KINDS OF GAS.

1178. Until recent years only one kind of gas was used for illuminating and heating purposes, and that was obtained by the distillation of bituminous coal. The demand for gas for heating purposes, however, became so great, that new processes were invented, and other varieties of gas have been introduced, so that now all forms of gaseous fuel are called by the general name of *gas*.

The varieties of gas now commonly used are as follows: Coal gas, oil gas, water gas, producer gas, natural gas, gasoline gas (or carbureted air), and acetylene.

1179. **Coal gas** is made by heating bituminous coal in air-tight boxes or retorts. The heat breaks up the combinations of hydrogen and carbon which exist in the natural coal, and transforms them into other compounds, most of which are gaseous at ordinary temperatures. Among the new compounds thus made are **tar, ammonia, and sulphureted hydrogen**. The tar condenses in the apparatus, and is pumped out. The ammonia is formed by the union of hydrogen with nitrogen, and has an offensive odor. Great care is taken to condense this mixture and remove it before the gas leaves the apparatus.

The worst impurity, however, is formed by the union of hydrogen with the sulphur contained in the coal. This is called sulphureted hydrogen. It is one of the vilest smelling substances known, and is very poisonous to breathe.

The odor of ordinary coal gas is due mainly to small traces of ammonia which remain in it. These impurities are removed by compelling the gas to flow in thin streams through pans filled with lime, oxide of iron, or other chemicals; or by causing it to bubble through bodies of liquid which have been charged with suitable chemicals. The former process is called **purification**, and the latter, **scrubbing**. The chemicals absorb the various impurities, while the gas undergoes no change, except cleansing.

1180. Oil gas is made from petroleum in a similar way, or from almost any variety of animal or vegetable oil, grease, or fat. Even oily refuse and city garbage have been used successfully for the production of gas.

Good illuminating gas can also be made from wood, peat, sawdust, in fact, almost any kind of combustible material, by substantially the same process.

1181. Producer gas differs from the coal gas commonly used for lighting purposes, in having much less combustible matter, and in having a large percentage of nitrogen. The average quality of producer gas contains 10 to 15 per cent. of hydrogen, and 20 to 30 per cent. of carbon monoxide. These constitute the combustible part of the gas, nitrogen forming about 40 to 60 per cent. of the total volume. This gas burns with a dull reddish flame, and its value for heating purposes is about one-fourth that of an equal volume of good coal gas.

Producer gas is made by burning coal, either bituminous or anthracite, in a closed furnace with a supply of air which is purposely made too small to permit of perfect combustion. The air is usually supplied by a steam-jet blower, and the amount is regulated so that it is barely sufficient to convert the carbon in the fuel into carbon monoxide, CO. The nitrogen in the air remains unchanged, and passes off into the gas pipes with the CO as an inert, useless accompaniment, merely swelling the total volume of the product.

1182. Water gas is a mixture of hydrogen and carbon monoxide, with only a very small percentage of nitrogen. It is made from anthracite coal or coke and steam. The coal, in lumps from 2 to 3 inches in diameter, is placed in an air-tight cylinder lined with firebrick. It is ignited, and blown up to a bright incandescent heat by means of an air blast; then the blast is shut off, and a current of dry steam is blown through the mass of glowing fuel. The great heat causes the steam to break up into free oxygen and hydrogen. The oxygen combines with the hot carbon, forming CO, and the hydrogen passes along with it, but without com-

binig. These are then led off through suitable pipes to a gas holder. As soon as the incandescent fuel becomes a little dull, or cooled, the steam is shut off, and the fire is again blown up bright with the air blast. The operations of *blowing up* and making gas are worked alternately at intervals of about five minutes, until the fuel is exhausted.

The fresh gas as thus made contains less carbon than good coal gas, and, consequently, will not burn with as bright a flame. It burns perfectly in heating burners, but when it is to be used for lighting purposes, it is always *enriched*, that is, made richer in carbon. This is done by vaporizing a quantity of petroleum by heat, and injecting it into the hot gas before it leaves the generator, continuing the injection until the percentage of carbon in the gas is raised to the desired standard.

Pure water gas is very light, having a density of about .4 that of air. It has very little odor and is, therefore, more dangerous than coal gas, because a considerable leak may exist without attracting much attention. In the process of manufacture, some of the impurities are allowed to remain, so as to give the gas an odor which is plainly perceptible.

1183. Water gas is also made from crude petroleum by a continuous process. This is known as **Archer gas**, from the name of the inventor of the apparatus. The oil is pumped in a small stream into a red hot retort, where it is quickly reduced to vapor by the heat. The oil vapor is then mixed with a current of superheated steam, and the mixture is driven through a long coil of very hot pipe. The oxygen of the steam unites with the carbon of the oil, forming CO , and the hydrogen is set free. The resulting gas is permanent, and is of high value for heating purposes. It is produced at a pressure of 8 to 10 pounds per square inch.

1184. **Natural gas** is obtained from holes or **wells** which are drilled in the earth. It is found in large

quantities in the vicinity of deposits of petroleum; and deposits of coal, both bituminous and anthracite, are always accompanied by greater or less quantities of gas of a very similar nature.

It is composed mainly of a compound of carbon and hydrogen, and is called **light carbureted hydrogen**. This often amounts to 90 per cent. or more of the total volume. Consequently, it will develop more heat per cubic foot in burning than any other kind of gas except acetylene.

Natural gas is produced at the wells under great pressure, and in common practice the pressure in the street mains and distributing pipes is allowed to be very much higher than is usual with manufactured gas.

1185. Acetylene.—This gas is a compound of carbon and hydrogen. Its chemical symbol is C_2H_2 , and its composition is 12 parts of carbon to 1 of hydrogen by weight, or 92.3 per cent. carbon and 7.7 per cent. hydrogen. The proportion of carbon is extraordinary, and the compound appears to be overloaded. It is known to be unstable, and the gas is liable to decompose spontaneously and explosively, under the action of a violent shock or blow. There is, therefore, some danger in handling and using it.

Its density compared with that of the air is .91, and its weight at 32° F. is .073 pound per cubic foot. It is without perceptible color, and it has a strong odor like garlic. It is poisonous to breathe, in about the same degree as ordinary illuminating gas.

The heat which it is capable of developing by burning is theoretically 1,090 heat units per cubic foot.

It is manufactured by an indirect process, and no direct process suitable for common use is at present known. The first step in the process is to form a compound of carbon with calcium. This is done by subjecting a mixture of coke and lime to the intense heat of an electric furnace. The product, which is called **carbide of calcium**, is a reddish brown or gray material, opaque, somewhat crystalline, and it decomposes water like ordinary quicklime.

When it is desired to produce acetylene, the carbide of calcium is put into water. Both materials decompose. The calcium takes up oxygen from the water, forming oxide of calcium, which is common quicklime. The carbon combines with the hydrogen of the water and forms the desired compound—acetylene. Considerable heat is given off during the operation.

Pure carbide of calcium will yield 5.4 cubic feet of acetylene per pound; but the commercial material is impure, and gives in practice $4\frac{1}{4}$ to $4\frac{3}{4}$ cubic feet per pound, at atmospheric pressure.

Acetylene gas, when burned in ordinary batswing burners, gives a dull, smoky flame, because the gas is not spread out sufficiently to secure from the air the oxygen required to burn the carbon properly.

To develop the full illuminating power of the gas, it is necessary to greatly enlarge the flame. This may be done by using a burner tip having the thinnest slit obtainable, and by giving the gas a heavy pressure—4 or 5 inches of water or more.

One valuable quality of acetylene is its ability to furnish lights of very small size but of great brilliancy. With a properly made burner, a light about $\frac{1}{8}$ inch in diameter can be made which will give the same illumination as an ordinary candle.

Carefully made tests show that acetylene will give a light of 240 candle power, when burned at the rate of 5 cubic feet per hour; while good, ordinary illuminating gas will average about 16 candle power at the same rate of consumption.

A flame giving a light of 20 candle power will consume about $\frac{1}{2}$ cubic foot of acetylene per hour; but to obtain this result, great care must be taken in the construction of the burner.

Acetylene can be reduced to liquid form, at a temperature of 60° , by a pressure of about 600 pounds per square inch; and it can then be stored in portable steel cylinders like other gases.

It corrodes silver and copper, and the compounds thus

formed are explosive. It does not affect brass, iron, lead, tin, or zinc. These facts should be borne in mind when constructing apparatus for its use.

1186. Gasoline gas, or carbureted air, also called air gas, is a mixture of gasoline vapor with air. The *pure vapor* is so rich in carbon that, in order to burn it successfully for lighting purposes, it must be given a high pressure; and special burners must be employed, as for acetylene.

The pure gasoline vapor contains a much greater amount of carbon per cubic foot than ordinary illuminating gas; and in order to burn it in the same burners and at the same pressure, it must be *diluted* with air until the proportion of carbon equals that in ordinary coal gas.

The air furnishes a part of the oxygen required for combustion, but it also introduces a large proportion of nitrogen, which is inert and useless material, being incombustible; and it operates to reduce the temperature of the flame, and thus to diminish its brilliancy.

Gasoline is produced by distilling crude petroleum. Its specific gravity is about .74 that of water. It is really a mixture of a large number of hydrocarbon compounds, which differ slightly in their chemical proportions. All of them, however, will change from the liquid to the gaseous form, under ordinary atmospheric pressure, at a temperature ranging from 70° to 100°. If a tank containing liquid gasoline be opened to the air, the liquid will all pass away in the form of gas. The rapidity of the evaporation will depend upon the temperature, being very slow at 40°, quite rapid at 70°, and furious at 212°; and, if the liquid catches fire in any way, it will pass into gas with explosive violence. The burning liquid expands enormously and is very difficult to extinguish. Gasoline must be regarded as gas in a liquid form, and it should be clearly understood that it will resume the gaseous form whenever the opportunity is afforded. The effect of leaving a can of gasoline uncorked is exactly the same as that of leaving a gas cock open; in both cases the

gas will diffuse through the atmosphere and form explosive mixtures.

It is generally regarded as a dangerous material to use or handle, but the danger arises from the recklessness or neglect of the persons using it. If the same care is taken to keep it shut up as is taken to keep coal gas confined, it is no more dangerous than the latter. A tank of gasoline should be treated as a *reservoir of gas*.

1187. Gasoline is put upon the market in several grades. The highest grade, sometimes called **winter gasoline**, will evaporate at ordinary temperatures and leave nothing behind. The poorer grades contain more or less oil which will not evaporate without the aid of heat; this oil collects in the gas-generating apparatus, and must be removed from time to time. It is usually thrown away, but it is very similar to low-grade kerosene, and will burn in the same manner in gasoline stoves.

The quantity of gasoline which is required to produce one thousand cubic feet of gas, and which will give a light of 14 to 16 candles (when burning at the rate of 5 cubic feet per hour), is about $4\frac{1}{2}$ gallons of the best grade, but more is required if the gasoline is of a lower grade.

GAS MACHINES.

1188. The apparatus used for making illuminating gas from gasoline consists of three parts: a generator for holding the gasoline, an air pump for forcing air through the generator, and a mixing device for mingling the air and vapor in proper proportions.

The vapor is made by simple evaporation, without the aid of heat. The liquid is spread out in large shallow pans, and the air is compelled to pass successively over its surface in all of the pans. The construction of the evaporator, or **generator**, is shown in Fig. 421. Three pans *a*, *b*, and *c* are employed, sometimes more, and all are enclosed in a gas-tight casing, having an opening *i* in the side for the inlet of air and another opening at *d* for the outlet of gas. Some

parts of the gasoline evaporate slowly, and it is necessary to have large evaporating surfaces, so that a proper amount of

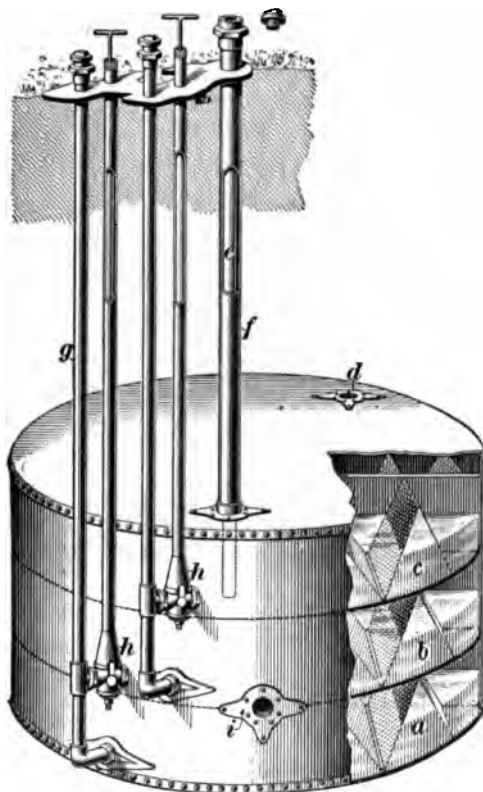


FIG. 421.

vapor will be given off when the lighter parts of the liquid have been evaporated and only the heavier parts remain. In order to increase the evaporating surface, the pans are partly filled with cotton or similar porous materials which absorb the gasoline, and the air is forced to pass partly through the mass of absorbent material. A common practice is to arrange some capillary material woven into a coarse fabric in the zigzag manner, as shown, so that the air will be compelled to flow

through the meshes of this netting, and thereby absorb the gasoline which is drawn up by capillary attraction.

1189. The generator is charged by pouring the gasoline down through the pipe *e* into the upper pan *c*. The pipe *f* through which *e* is slipped forms an outlet tube for air while the generator is being filled with gasoline. When this pan becomes full, the liquid overflows into the next pan below, and thus they are all filled successively. Should the bottom pan become too full, the excess may

be pumped out by attaching a pump to the top of the tube *g*.

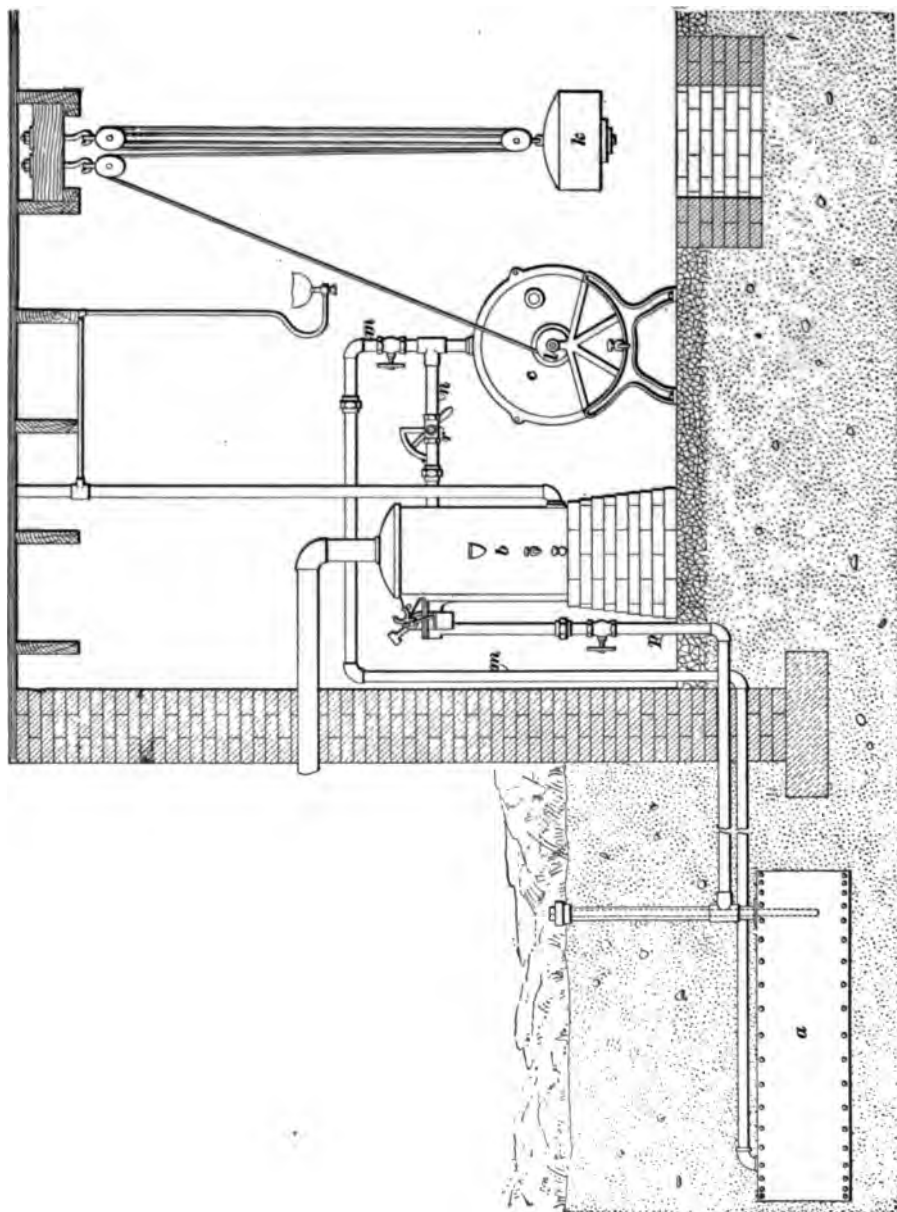
When the lighter parts of the gasoline have been evaporated from any one pan, the remainder is usually dropped into the next pan below by opening one of the cocks *h*. The waste liquid collects in the bottom pan and may be removed from time to time by pumping through the tube *g*.

The generator is buried in the earth outside of all buildings, for fear of possible explosions. It must be buried deep enough to avoid all risk of freezing; because at temperatures below 32° the liquid evaporates too slowly to answer the purpose. The handles of the valves and all of the pipes needed for testing and filling are extended upwards to the surface of the ground, and are protected from the weather by a suitable water-tight box and cover. It was formerly customary to place the generator in an underground vault. The advantage of this arrangement was that the generator was fully accessible; but the construction of the vault increased the total cost of the apparatus so much that the plan has been nearly abandoned. The buried generators need to be strongly built to stand the pressure of the earth around and above them.

1190. The *air pump* may be of any variety desired, but the kind commonly used is shown in Fig. 422. It closely resembles the wet gas meter (see Fig. 375) in construction and principle, except that the drum is rotated by power so as to act as a force pump instead of as a meter. The drum is turned by means of a heavy weight *k* and a cord which is wound around the pulley *l*. It turns very slowly, even when working at full speed. The weight is required to be wound up at intervals of three to four days or more, according to the demand for gas.

The pump should take air from some place which is never at a freezing temperature, because cold air will check evaporation in the generator.

The body of the machine is filled with water up to a



certain mark, which is usually visible through a mica *bull's-eye*. The water evaporates slowly, and must be replenished from time to time. The air is driven through the pipe *m* to the generator *a*, and returns mixed with vapor through the pipe *p*.

1191. When the gasoline is cold, or is nearly spent, it is necessary to change the proportions of the air and vapor in order to maintain the illuminating power of the gas at the standard desired. Otherwise, the gas will be too rich, that is, it will contain too much carbon; consequently, it will smoke in summer time, and will burn pale and blue in very cold weather. This difficulty is sometimes met by using adjustable burners, but the drawback to that arrangement is that all of the burners must be adjusted at intervals, to suit the varying quality of the gas.

If a mixing device is used, then all the necessary adjustment can be made at one point, and ordinary batswing burners may be used without any trouble.

1192. The **mixing device** consists of a by-pass pipe *n*, connecting the air pipe *m* with the gas pipe *p*. It is provided with a cock *r*, having an index and pointer, by which it can be adjusted to any desired amount of opening. The mixing device is not automatic, but must be adjusted by hand.

When the apparatus runs very slowly, or stands still for a while, the gasoline vapor with a direct connection will diffuse throughout the pipes *m* and *n* and back into the pump. The mixer is then useless. This trouble may be prevented by means of the regulator shown in Fig. 423, which is an enlarged sectional drawing of the regulator *b* in Fig. 422.

The gas coming from the generator is introduced at *c*, and the air from the by-pass pipe is brought in at *d*. Both openings are controlled by a slide valve *f*. The gas is discharged into the distributing pipe at *g*. When gas is passing through the machine, the drum *a* alternately fills and empties, rising and falling in the water tank *b* as it does so.

When it rises it fills with gas from *c* and fresh air from *d*, according to the adjustment of the by-pass cock. When it

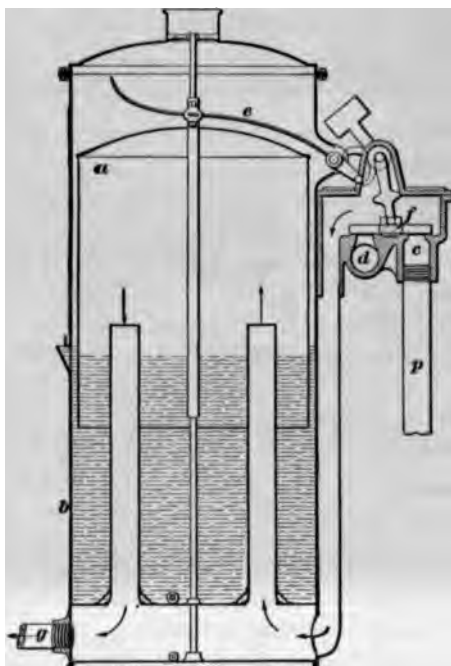


FIG. 428.

reaches the top of its stroke, it moves the lever *e* and closes the valve *f*. The mixture within the drum is thus cut off from all communication with the generator or the pump; consequently, its proportions can not be changed by standing for any length of time. When the drum sinks to the bottom of its stroke and is nearly empty, it moves the lever *e* in the opposite direction, and opens the valve *f*, thus admitting a new charge. The water in the tank

gradually evaporates when the machine is in use, and it is necessary to replenish it occasionally.

1193. When a poor grade of gasoline is used in making the gas, the generator gradually becomes clogged with an oil which will not evaporate freely, and which for the purpose of gas-making is spent and useless. This is generally pumped out and thrown away. It should not be thrown into a drain or a sewer, because it will fill them with explosive gas. It should not be thrown into a stream of water, because of the danger from fire to everything adjoining the water, and because of the stench to which it will give rise. The whole trouble may be avoided by using a better grade of gasoline.

All of the pipes in the gas apparatus, and the house pipes as well, must be kept out of the reach of frost, and if they are exposed they must be well protected. The pipes must be graded and drained, and provided with drip cups in the same manner as with coal gas, etc. A low pressure is generally used throughout the system of distributing pipes, and, therefore, the pipes are usually made a little larger than for coal gas. (See Table 41, Art. 1089.)

The apparatus used for making gas from gasoline for manufacturing purposes is much more simple than that described here. The air is supplied by a common steam pump at a pressure of 3 or 4 pounds per square inch. The gasoline is contained in strong vertical cylinders, which are loosely filled with cotton or other absorbent fibers, and the air is forced through the mass. The temperature of the air is raised a few degrees by the process of compression, and the warmth aids the evaporation of the gasoline. The quality of the gas is maintained at any desired standard by pumping fresh gasoline into the generator whenever it is required. In some forms of apparatus, the evaporation of the gasoline is aided by the application of a moderate steam heat.

When gas is formed by the aid of heat, care must be taken to prevent it from cooling to any considerable extent, because a part of it will then condense into liquid form again.

LIGHT.

PROPERTIES OF LIGHT.

1194. The nature of light is the subject of much speculation, and it is deemed unnecessary for the purpose of this paper to present a theory of its constitution or origin.

Light can be measured only by its illuminating effects. As it can not be absorbed and stored, as may be done with heat, quantitative measurements are impossible. The methods and apparatus for measuring the intensity of light will be described later.

INTENSITY.

1195. Light diminishes in intensity as it recedes from the luminous body, according to the same law that governs all other radiant forces, such as heat, electricity, sound, etc.

The intensity varies inversely as the square of the distance from the source of light.

Thus, if the two equal surfaces, *A* and *B* in Fig. 424, be illuminated by the same lamp, *A* being 2 feet away from it

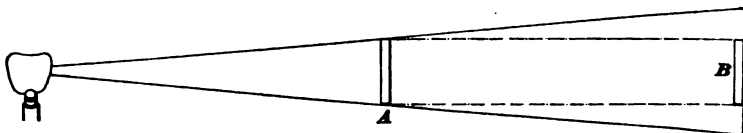


FIG. 424.

and *B* 4 feet, then *B* will receive less light than *A*, in inverse proportion to the squares of their relative distances, or $2^2 : 4^2$, which equals $\frac{1}{4}$.

That this law must be true is evident from an inspection of the figure. The light which is intercepted by *A*, if permitted to proceed, will illuminate an area at *B* which is twice as high and twice as wide as *A*. The same amount of light is thus spread over 4 times the area of surface, and, consequently, it can have but one-fourth the brilliancy.

PROPAGATION OF LIGHT.

1196. Light proceeds from a luminous body equally in all directions. It always moves in straight lines unless the medium through which it passes varies in density. Thus, if it passes through a body of air which is warmer in one part than in another, it will be deflected, and the object viewed will appear out of its true position.

REFRACTION.

1197. When light falls obliquely upon a plate of glass, its direction is changed within the interior of the glass; this change of direction is called **refraction**. When the light emerges from the opposite surface of the glass, its

direction is again changed. If the surfaces are parallel, the light will resume its former direction, as shown at *A*, Fig. 425; but if they are not parallel, then the ray will be permanently deflected from its course, as shown at *B* in the same figure. Upon entering the glass, the ray of light *a* will be bent or refracted to the line *d*, thus making a *larger* angle with the surface of the glass than the original ray. When it leaves the glass it will be again bent, but to a smaller angle with the surface from which it emerges. If



FIG. 425.

an object at the point *c*, in either case, be looked at from the point *a*, it will appear to be located at *b*.

The refractive powers of glass, ice, crystals, water, oil, and gas differ greatly. Any of these substances may be employed, in the form of lenses, to concentrate or disperse light. A certain variety of crystal, called *Iceland spar*, refracts light twice simultaneously, causing objects seen through it to appear double.

DISPERSION OF LIGHT.

1198. Light which is scattered in many directions is said to be **dispersed**. Thus, light is dispersed by reflecting it from a roughened or corrugated surface, or by transmitting it through a shade or screen of glass having a frosted or corrugated surface.

Light which is transmitted through white or opal glass is not dispersed, but is merely reduced in intensity. Usually, however, the surfaces of such shades are corrugated, and more or less dispersion is produced thereby.

One of the best materials for dispersing light is frosted or ground glass.

REFLECTION.

1199. When light falls upon a mirror, part of it will be turned back or turned aside from its original path. This change of direction is called *reflection*.

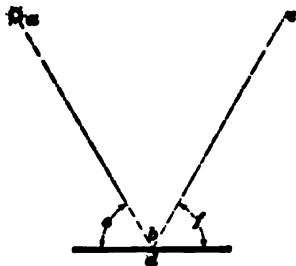


FIG. 426.

The proportion of light which will be reflected varies with different materials, with the condition of the reflecting surface, and with the angle at which the light strikes the reflector.

That part of the light which proceeds from the lamp to the mirror, as *ab* in Fig. 426, is called the **incident ray**, and the part which is reflected, as *bc*, is called the **reflected ray**.

The law which governs the direction of the reflected ray is as follows:

*The angle made by the reflected ray with the surface of the mirror will always equal that made by the incident ray; that is, the angle *f* always equals the angle *c*.*

If the mirror is curved, as in Fig. 427, the angles are measured to the line *hi*, which is a true tangent to the curve at the point *b*, where the ray strikes the mirror.

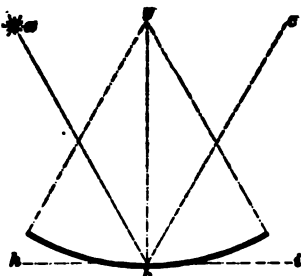


FIG. 427.

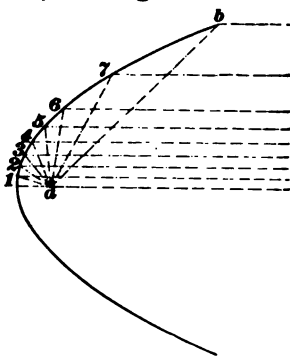


FIG. 428.

REFLECTORS.

1200. Reflectors should be made of brightly polished metal, or of silvered glass attached to a metal frame or backing. The silvered glass will not endure much heat; consequently, the polished metal should be used if the heat from the burners is likely to be excessive.

The most effective reflectors are those having the outline

of a parabola, with the flame at the focus. All of the rays which are received upon the reflector are then reflected in parallel lines, as shown in Fig. 428. The angles formed by the dotted lines $a 1$, $a 2$, $a 3$, etc., are all equal; consequently, the volumes of light reflected through the spaces enclosed by the dotted parallel lines are also equal. The method of outlining a reflector of this kind is shown in Fig. 429. The first things to be determined are the width $b c$ to be given to the reflector and what proportion of the total light emitted from the flame shall be caught and projected forwards. The center of the flame is indicated by the dot a , and the lines $a b$ and $a c$ are drawn so as to include the desired proportion of light. In the figure the reflector is designed to reflect three-fourths of the total light.

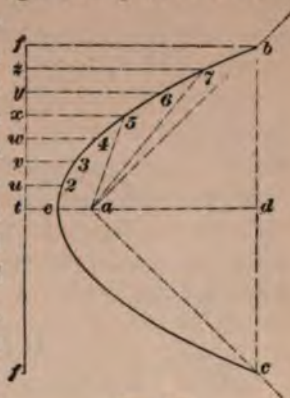


FIG. 429.

The desired width $b c$ is then laid off upon these lines, and the points b and c are established. The line $f f$ is then drawn parallel to $b c$, and the distance $f b$ is made equal to $a b$. Now, any point in the true curve $b e c$ may be located by making it equally distant from the focus a and the line $f f$; thus, the distance $a 7 = z 7$; $a 5 = x 5$, etc. The distance from a to the apex of the curve at e is exactly one-half of the distance $a t$. The curve thus delineated is a true parabola.

Some text-books show a method of drawing parabolas by means of a T square and a string. While the method is theoretically correct, in practice it is unreliable and worthless.

1201. Fig. 430 shows a parabolic reflector designed for a *sun light*. It is made in halves which are separated a distance equal to that between the centers of the gas flames a and b .

Large and expensive reflectors are often erected with very unsatisfactory results. The trouble usually arises from the

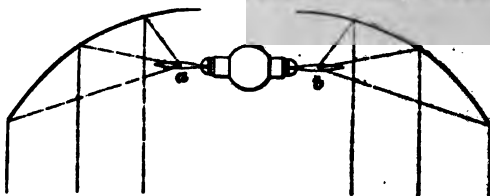


FIG. 430.

fact that no effort was made to adapt the *shape* of the reflector so as to produce the effect desired.

Heat is reflected in the same manner as light, and it follows the same law of intensity. It may be concentrated by means of parabolic reflectors more effectively than by any other device.

ILLUMINATION.

1202. The ideal of artificial illumination is to have the light coming from overhead, and to have it so thoroughly diffused that no object in the room shall appear conspicuously brighter than any other.

While it is impracticable to attain this ideal, with the means at hand at the present time, yet it should be so kept always in mind that mistakes in lighting may be avoided.

Lights of great brilliancy, such as electric arc lights, not only dazzle the eye, but frequently produce blindness. Oculists strongly condemn them, because they impair the vision of persons using them. The trouble is due mainly to the brilliancy of the light.

In using artificial lights for illumination, the aim should be to illumine all objects within the ordinary field of vision to about the same degree of brilliancy as that afforded by *diffused* daylight. Objects which are lit up by direct sunlight are usually too bright to look at continuously.

The flames of gas burners or lamps are much too bright to be looked at directly; therefore, they should be screened so that whatever light reaches the eye shall be reduced to a moderate intensity.

1203. The physiological effect of a light which shines in the eyes of a person who is looking at something else is to produce considerable nervous irritation and fatigue, if long continued. Thus, if a gas burner or kerosene lamp, or any bright object, comes within the ordinary field of vision while a person is listening to an address, and is looking towards the speaker, it will cause a great deal of uneasiness. A few lights misplaced in that way will fatigue an audience to a greater degree than is generally supposed. Therefore, all lights which are located in the vicinity of a person addressing an audience, either above or behind, or at either side, should be fully covered by opaque screens which will prevent any light from passing towards the audience.

While the irritating brilliancy of such lights may be mitigated by means of globes of white or opal glass, yet they continue to be conspicuously bright, and are very objectionable. The best result is obtained by using opaque screens which reflect the light back upon the platform.

For similar reasons all chandeliers or pendants should be hung so high that the lights will not come within the field of vision of any person looking towards the platform or speaker.

1204. Large audience rooms, such as churches and lecture rooms, can be illuminated to best advantage by means of groups of small burners which are located near the ceiling, and are provided with proper reflectors to project the light downwards. These sun lights may be arranged in a great many ways, and can be adapted for almost any kind of service. The light which they give is more agreeable than that from a single burner of equal power, because it proceeds from a large number of flames, and is thus so diffused that the shadows are very *soft* or indistinct.

This method of lighting is correct in principle, and it should be employed for domestic lighting to a much greater extent than it is at present. While there are some difficulties in carrying out the plan on a small scale, yet these should act as a stimulus to invention rather than as a bar to

improvement. The introduction of the modern high-power lamps, such as the Wenham regenerative and the Welsbach incandescent, makes it very necessary that great improvements be made in the modes of distributing and diffusing light. There is a great need of such improvements for domestic illumination.

Flat gas flames, when turned horizontally, give a brighter illumination to objects below them than when burning in the ordinary erect position. The gas flames in overhead sun lights should always be horizontal.

AMOUNT OF LIGHT REQUIRED.

1205. Rooms having dark colored walls, or having much colored drapery, will require more light than they would if finished in white. The white walls reflect and disperse the light, thus aiding the general illumination, while colored walls reflect less in proportion to the brightness of their coloring.

1206. The rule commonly used for computing the number of ordinary 5-foot batswing burners which will be required to properly illuminate a church or other large room is as follows:

Rule.—*Divide the area of the floor of the room by 40; the quotient will be the number of burners required.*

If there are balconies, etc., extra lights must be provided for them by the same rule. The divisor given may be varied from 40 to 80 to suit smaller rooms such as are found in ordinary dwellings. The reflection from the walls is proportionally greater in small rooms; therefore, a less number of burners is required in proportion to the actual floor space.

EXAMPLE.—How many 5-foot batswing burners will be required to properly illuminate a church having an auditorium 70 ft. $\times$ 100 ft., and a balcony having 2,000 square feet floor area?

SOLUTION.—The main floor will require $\frac{70 \times 100}{40} = 175$ burners, and the balcony will require $\frac{2,000}{40} = 50$ burners; $175 + 50 = 225$ burners.

Ans.

1207. One 5-foot burner is assumed to give a light of 16 candle power. The amount of light required is, therefore, 16 candle power to a floor space of 40 square feet in large rooms, to 80 in small ones, or .4 to .2 candle power per square foot of floor space.

PHOTOMETRY.

1208. The capacity of the human eye for the perception of light is comparatively small. It is unable to perceive very faint lights, and it is dazzled and confused by lights of great brilliancy. Photographic plates are affected by faint lights which are invisible to the eye; thus, photographs of the sky reveal a multitude of stars which are not visible even with the aid of the strongest telescopes. The unaided eye is unable to judge of the relative intensity of various lights with any reasonable approach to accuracy.

1209. The art of measuring the comparative intensity of lights is called **photometry**. There are several methods of making these measurements—chemical, electrical, and mechanical, each of which is peculiarly suited to special cases. The method employed for general purposes is to compare the illuminating power of the light under examination with that of a light of standard intensity.

1210. The **unit** which is used for all ordinary measurements is the light given by a sperm candle which burns at the rate of 120 grains per hour.

The candle is burned in still air, and care is taken to avoid all drafts which might accelerate the combustion, and thus vary the brilliancy of the light. The light thus obtained is made the unit for comparison, and is called one **candle power**.

1211. A larger unit is sometimes used for measuring very large lights. This is the flame of a certain variety of oil lamp called the Carcel lamp, and the unit thus derived is called one **Carcel**.

PHOTOMETERS.

1212. All instruments which serve to measure the comparative brilliancy of lights are properly called **photometers**, but only those which are suitable for measuring ordinary gas lights, etc., will be described here.

1213. One of the oldest of these instruments, called the **Rumford photometer**, is shown in Fig. 431. It con-

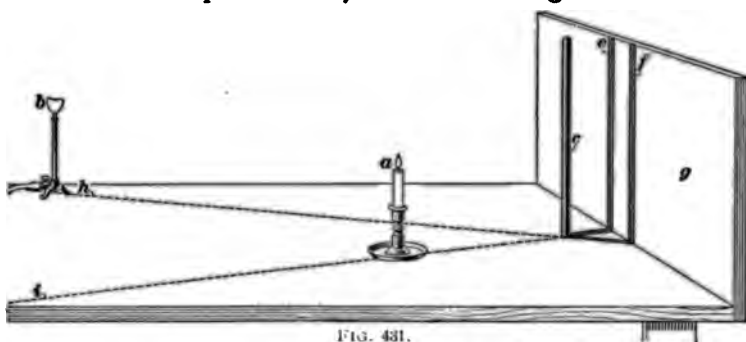


FIG. 431.

sists of a table having a black wooden post *c*, standing erect, as shown, and a screen *g*, which receives the shadows of the post that are cast by the lights *a* and *b*. The candle *a* is the standard light, and *b* is the light whose intensity is to be measured. The lines *bc* and *ac* make exactly equal angles with the screen, and the lights are moved back and forth along these lines until the shadows *e* and *f* appear of exactly equal blackness. The powers of the two lights are then computed by dividing the powers of the two lights by the square of the distance *ac*, the quotient being the candle power of the light *b*.

This method is very inaccurate, and is not to be recommended, because the eye is unable to compare the shadows *e* and *f* with the requisite accuracy.

1214. The **Bunsen photometer**, shown in Fig. 432, operates upon a different principle. A diaphragm *c* is illuminated on its opposite sides by the light *b* and the standard candle *a*. The observer looks down through the tube *e* into mirrors *f* and *g*, and thus sees the reflection of

both sides of the diaphragm at the same time. If they appear of unequal brilliancy, the *sight-box* *d* is moved along the bar *h* until they become equal. The candle power of the light *b* is then found by dividing the square of the dis-

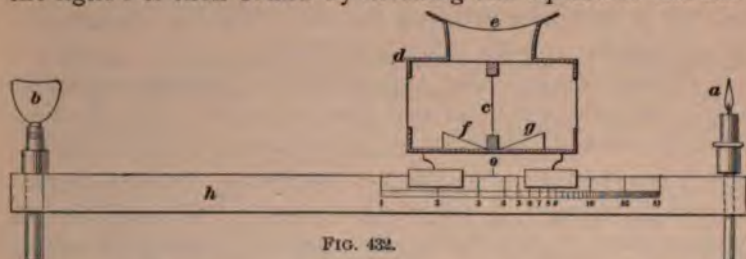


FIG. 432.

tance *b c* by the square of the distance *a c*; usually the bar is graduated, as shown, so that no calculation is necessary.

1215. There are two methods in vogue of constructing the diaphragm. The **spot** diaphragm is shown in Fig. 433. The center *a* is a disk of opaque white paper. The ring *b* is made of white paper which is saturated with paraffin, and is translucent. The outer part *c* is blackened. When this diaphragm is unequally illuminated on its opposite sides, the ring *b* looks darker, or brighter, than the center *a*, but when the illumination is exactly equal, all difference disappears, and the spot *a* becomes indistinguishable.



FIG. 433.

1216. The **star** diaphragm is shown in elevation at *A*, and in section at *B* in Fig. 434. It consists of a piece of white writing paper *a* of moderate thickness, having a star-shaped figure cut out of its center, and a sheet of thin white writing paper *c*, of best quality, which is doubled so as to enclose the piece *a*. The diaphragm is lightly squeezed between two pieces of glass



FIG. 434.



It consists of a piece of white writing paper *a* of moderate thickness, having a star-shaped figure cut out of its center, and a sheet of thin white writing paper *c*, of best quality, which is doubled so as to enclose the piece *a*. The diaphragm is lightly squeezed between two pieces of glass

b, b. Care is taken in cutting the star to make every point and line clear and sharp. When the reflection of the diaphragm is seen in the mirrors, the images will vary in *distinctness* if the lights are unequal. The sight-box *d* in Fig. 432 is then moved along the bar until both images of the star appear equally sharp and clear.

It will be observed that the methods of testing employed in the photometers described are quite different. In the Rumford method the observer judges the equality in blackness of the shadows produced; in the Bunsen method, using the *spot* diaphragm, he judges by the equal brightness of the opposite sides of the diaphragm, and when using the *star* diaphragm, he judges by the equal clearness and distinctness of the two images of the star.

The Rumford method has been discarded for the more accurate Bunsen method. Both the spot and star diaphragms are widely used; but the star diaphragm is preferred because of its superior accuracy.

1217. In practice the distance between the centers of the lights, Fig. 432, is usually made 100 inches, and the bar is graduated according to the following table, the numbers given being the distance in inches from the center of the candle flame to the center of the diaphragm for each candle power:

TABLE 42.

1	50.00	11	23.17	21	17.91	31	15.22
2	41.42	12	22.40	22	17.57	32	15.02
3	36.61	13	21.71	23	17.25	33	14.83
4	33.33	14	21.09	24	16.95	34	14.64
5	30.90	15	20.52	25	16.67	35	14.45
6	28.98	16	20.00	26	16.40	36	14.28
7	27.43	17	19.52	27	16.14	37	14.12
8	26.12	18	19.07	28	15.90	38	13.96
9	25.00	19	18.66	29	15.66	39	13.80
10	24.04	20	18.27	30	15.43	40	13.65

The distance x (equal to ac in Fig. 432) for any candle-power (c.p.) for any distance L between centers of the lights may be computed by dividing L by 1 plus the square root of the candle power; thus, $x = \frac{L}{1 + \sqrt{\text{c.p.}}}$.

1218. Any good mechanic can construct a photometer like Fig. 432, which will be sufficiently accurate for all ordinary purposes. By its aid he can investigate for himself, and can acquire much valuable information.

In using the photometer care must be taken to prevent the entrance of light into the sight-box from any other source than the lights which are to be compared. A screen of black velvet should be suspended behind each light to prevent any light from being reflected towards the sight-box.

It is not necessary to have a darkened room to operate in if the instrument is properly protected with curtains and screens of black cloth.

In testing gas, the pressure must be kept uniform, and the rate of combustion should be carefully measured. Standard candles can be obtained from the American Meter Co., New York.

The candle power of ordinary illuminating gas is measured while burning at the rate of 5 cubic feet per hour, under a pressure of .5 inch of water. To secure very exact measurements, small corrections must be made for the temperature of the gas and for the moisture contained in it.

The candle should always be weighed before and after each test, and allowances must be made in computing the candle power of the light under examination if the rate of consumption of the candle varies either way from the standard rate of 120 grains per hour.



1

ELECTRIC-LIGHT WIRING AND BELL WORK.

ELECTRIC-LIGHT WIRING.

FUNDAMENTAL PRINCIPLES.

1219. An electric current may be produced commercially by means of either a primary battery or a dynamo-electric machine. The elementary form of battery is simply a vessel *A*, Fig. 435, containing alkaline or acidulated water, into which dip two plates, one of which *C* may be copper, and the other *Z*, zinc. If two wires be secured to these plates and their ends brought together, a current will flow through them from the copper to the zinc, and will be interrupted when they are separated. The copper is then said to be the positive pole, or **negative element**, and the zinc the negative pole, or **positive element**, while the liquid is called the **electrolyte**. The path of the current from one plate through the liquid to the other plate, and through the wire to the starting point, is called the **electrical circuit**.

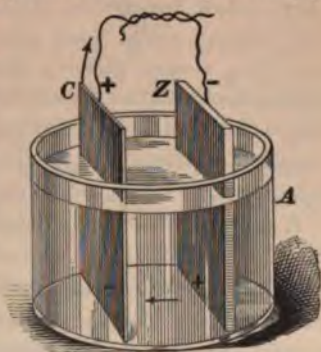


FIG. 435.

1220. A circuit is **broken**, or **opened**, when its conducting elements are disconnected in such a manner as to prevent the current from flowing.

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P. II.—29

A circuit is **closed**, or **completed**, when its conducting elements are so connected as to allow the current to flow.

A circuit in which the earth, or ground, forms part of the conducting path is called an **earth**, or a **grounded**, circuit.

The **external** circuit is that part of a circuit which is outside, or external, to the electric source.

The **internal** circuit is that part of a circuit which is included within the electric source.

In the case of the simple voltaic cell mentioned in Art. 1219, the *internal circuit* consists of the two metallic

plates, or elements, and the electrolyte; an *external circuit* would be a wire or any conductor connecting the free ends of the electrodes.

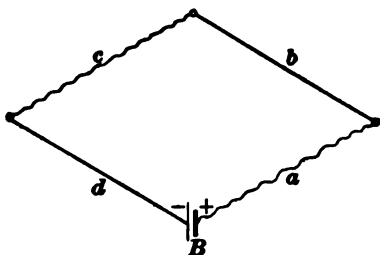


FIG. 436.

plates, or elements, and the electrolyte; an *external circuit* would be a wire or any conductor connecting the free ends of the electrodes.

1221. Conductors are said to be connected in **series** when they are so joined together as to allow the current to pass consecutively through each. For example, Fig. 436 represents a *closed* circuit consisting of a simple voltaic cell *B*, and four conductors *a*, *b*, *c*, and *d*, connected in *series*.

A circuit which is divided into two or more branches, each branch transmitting part of the main current, is a **derived**, or **shunt**, **circuit**, and the separate branches are said to be connected in **parallel**, or

multiple-arc. An example

of a *derived* circuit, of two branches in *parallel*, is shown in Fig. 437. The main current flows first through the conductor *a*,

then divides between the branches *c* and *b*, and finally unites, completing the circuit through the conductor *d*; the two branches *c* and *d* are the conductors which are connected in *parallel*, or *multiple-arc*.

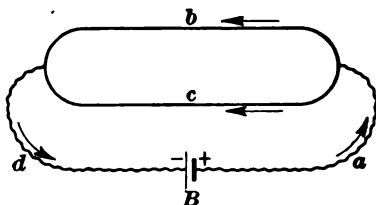


FIG. 437.

1222. In every circuit containing a battery, there is at all times a tendency for a current to flow, even when the circuit is open, which is caused by the fact that there is always an electrical pressure acting. It is as though we had a tank full of water, and a stop-cock at the bottom communicating with a pipe. The pipe represents the wire of a circuit. There is always a pressure on the stop-cock, and, directly we open it, a current of water flows through the pipe. The *amount* of water which would run out in a given time, say one minute, would depend on the size of the pipe; if it were of large cross-sectional area, more water would flow than if it were small, because the larger pipe offers less resistance. Another condition would also influence the rate of flow, namely, the height of water. If the tank were very high above the outlet, the pressure would be great. The flow, then, of water depends on the resistance offered, and on the pressure applied; the less the resistance or the greater the pressure, the more water will be forced through. The same holds good with respect to electricity. If the resistance of the circuit is low and the pressure high, a large current will flow; if the resistance is great, less current will pass, unless the pressure be raised to such a point as to overcome the increased resistance. This is the explanation of the fundamental law in electrical calculations, known as **Ohm's Law**.

1223. Ohm's Law.—*The strength of an electric current in any circuit is directly proportional to the electromotive force developed in that circuit and inversely proportional to the resistance of the circuit; i. e., is equal to the quotient arising from dividing that electromotive force by the resistance.*

Ohm's law may be expressed thus:

$$\text{Strength of current} = \frac{\text{electromotive force}}{\text{resistance}}.$$

1224. The three principal units used in practical measurements of a current of electricity are:

(a) *The ampere, or the practical unit denoting the rate of flow of an electric current, or the strength of an electric current.*

(b) *The ohm, or the practical unit of resistance.*

(c) *The volt, or the practical unit of electrical potential or pressure.*

The usual form in which Ohm's law is given is

$$C = \frac{E}{R}.$$

The electromotive force, or pressure (E), is here expressed in *volts*, the resistance (R) in *ohms*, and the current (C) in *amperes*.

THE AMPERE.

1225. The strength of an electric current can be described as a *quantity* of electricity flowing continuously every second; or, in other words, it is the rate of flow of electricity just as the current expressed in *gallons per minute* is the *rate of flow* of liquids. When one unit quantity of electricity is flowing continuously every second, then the rate of flow, or the strength of current, is *one ampere*; if two unit quantities are flowing continuously every second, then the strength of current is *two amperes*, and so on. It makes no difference in the number of amperes whether the current flows for a long period or for only a fraction of a second; if the quantity of electricity that would flow in one second is the same in both cases, then the strength of the current in *amperes* is the same.

THE OHM.

1226. The unit of electrical resistance, now universally adopted, is called the **international ohm**. One international ohm is the resistance offered by a column of pure mercury 106.3 centimeters in length and 1 square millimeter in sectional area at 32° F., or the temperature of melting ice. The dimensions of the column expressed in inches are as follows: length, 41.85 inches; sectional area, .00155 square

inch. Hereafter, the word "international" will be omitted, and simply the word "ohm" used; the *international ohm*, however, as defined above, will always be implied unless otherwise stated.

In the accompanying table are given various data respecting the copper wire used in electrical installations. In the first column is the gauge number by American wire gauge; in the second column is the diameter as measured in *mils* (one mil=one one-thousandth of an inch); the third column shows the area of cross-section in circular mils. It is usual to adopt this method for a round wire, instead of the old way of expressing the area in fractions of a square inch, in which case the diameter is squared and the product multiplied by .7854, as explained in the section on Mensuration. If the second operation be omitted, and the diameter, as measured in thousandths of an inch, be only squared (or multiplied by itself), the result is expressed in circular thousandths, or circular mils.

EXAMPLE.—What is the area in circular mils of a wire $2\frac{1}{2}$ in. in diameter?

SOLUTION.— $2\frac{1}{2}$ in. = 2,500 mils. $2,500^2 = 2,500 \times 2,500 = 6,250,000$ circular mils. Ans.

The resistance of copper wire being low, a unit length of 1,000 feet is usually taken in tables of resistance, and this unit is considered in the eighth column. The resistance of a given conductor increases as the length of the conductor increases; that is, the resistance is directly proportional to the length of the conductor. For example, if the length of a conductor be doubled, its resistance will be doubled.

1227. The resistance of any length of conductor may be found by the following formula:

$$R = \frac{L R_1}{1,000}$$

where R = the required resistance;
 L = length of conductor;
 R_1 = resistance per 1,000 ft. of conductor.

TABLE 43.
AMERICAN, OR B. & S. GAUGE.

Gauge No.	Diameter Mils (d), 1 mil = .001 in.	Area.		Weight and Length.			Resistance. Ohms per 1,000 Feet.	Current Allowed. Amperes	Gauge No.
		Circular Mils (d^2).	Square Inches ($d^2 \times .7854$).	Pounds per 1,000 Feet.	Pounds per Mile.	Feet per Pound.			
0000	460.000	211,600.00	.166190	639.33	3,375.7	1.56	.051	175	0000
000	409.640	167,805.00	.131790	507.01	2,677.0	1.97	.064	145	000
00	364.800	133,079.00	.104520	402.09	2,123.0	2.40	.081	120	00
0	324.950	105,592.00	.082932	319.04	1,684.5	3.13	.102	100	0
1	289.300	83,694.00	.065733	252.88	1,335.2	3.95	.129	95	1
2	257.630	66,373.00	.052130	200.54	1,058.8	4.99	.163	70	2
3	229.420	52,634.00	.041339	159.03	839.68	6.29	.205	60	3
4	204.310	41,742.00	.032784	126.12	665.91	7.93	.259	50	4
5	181.940	33,102.00	.025998	100.01	528.05	10.00	.326	45	5
6	162.020	26,250.00	.020617	79.32	418.81	12.61	.411	35	6
7	144.280	20,817.00	.016349	62.90	332.11	15.90	.519	30	7
8	128.490	16,509.00	.012966	49.88	263.37	20.05	.652	25	8
9	114.430	13,094.00	.010284	39.56	208.88	25.28	.824	20	9
10	101.890	10,381.00	.0081532	31.37	165.63	31.88	1.040	20	10
11	90.742	8,234.10	.0064670	24.88	137.37	40.20	1.311	15	11
12	80.808	6,529.90	.0051286	19.73	104.18	50.69	1.653	15	12
13	71.961	5,178.40	.0040671	15.65	82.632	63.91	2.084	10	13
14	64.084	4,106.80	.0032254	12.41	65.525	80.59	2.628	10	14

Rule.—To find the resistance of any length of wire, divide that length in feet by 1,000, and multiply by the figure giving the resistance of that wire per thousand feet, as found in Table 43.

EXAMPLE.—What is the resistance of a No. 4 wire 1,530 feet in length?

SOLUTION.—The resistance per 1,000 feet of No. 4 wire is, from the table, .259 ohm = R_1 . The length = 1,530 ft. = L . Then, by the above formula, the required resistance

$$R = \frac{1,530}{1,000} \times .259 = .396 \text{ ohm. Ans.}$$

1228. The resistance of a given conductor diminishes as its sectional area increases; that is, the resistance varies inversely as the sectional area of a conductor. For example, if the sectional area of a conductor be doubled, its resistance will be halved.

EXAMPLE.—No. 8 wire has a resistance of .652 ohm per 1,000 feet. What will be the resistance of 1,000 feet of a wire having three times the sectional area of No. 8 wire?

SOLUTION.—A wire three times the area of No. 8 will have one-third its resistance, or $\frac{.652}{3} = .217 \text{ ohm. Ans.}$

The resistance of two or more conductors connected in *series* (Art. 1221) is equal to the sum of their separate resistances. For example, if four conductors, having separate resistances of 8, 12, 22, and 34 ohms, respectively, are connected in series, their total, or joint, resistance would be $8 + 12 + 22 + 34 = 76 \text{ ohms}$.

1229. The **microhm** is a unit of resistance devised to facilitate calculations and measurements of exceedingly small resistances, and is equal to *one millionth* ($\frac{1}{1,000,000}$) of an *ohm*. Hence, to express the resistance in *microhms*, multiply the resistance in *ohms* by 1,000,000; and, conversely, to express the resistance in ohms, divide the resistance in microhms by 1,000,000. For example, $.75 \text{ ohm} = .75 \times 1,000,000 = 750,000 \text{ microhms}$; or, $750,000 \text{ microhms} = 750,000 \div 1,000,000 = .75 \text{ ohm}$.

1230. The **megohm** is a unit of resistance intended for the measurement of very high resistances, such as the insulation of cables, and is equal to one million (1,000,000) ohms. Hence, to express the resistance in megohms, divide the resistance in *ohms* by 1,000,000, and, on the other hand, when the resistance in megohms is given, multiply by 1,000,000 in order to express the same in ohms. For example, 12,500,000 ohms = $12,500,000 \div 1,000,000 = 12.5$ megohms; or, 12.5 megohms = $12.5 \times 1,000,000 = 12,500,000$ ohms.

THE VOLT.

1231. In mechanics, pressures of all kinds are measured by the *effects* they produce. Similarly, in electro-technics, *potential* is measured by the effect it produces, and the *volt*, or *practical unit of potential*, is that electromotive force which will maintain a current of *one ampere* in a circuit whose resistance is *one ohm*. With a known resistance in ohms and a known strength of current in amperes, the electromotive force in volts is determined by Ohm's law, Art. 1223, for, by transposing, $E = C R$.

DROP, OR LOSS, OF POTENTIAL.

1232. Referring again to water flowing in a pipe, though the *quantity* of water which passes is the same at any cross-section of the pipe, the *pressure per square inch* is not the same. Even in the case of a horizontal pipe of the same diameter throughout, the water when flowing suffers a *loss* of head, or pressure. It is this difference of pressure that causes the water to flow between two points against the friction of the pipe.

This is precisely similar to a current of electricity flowing through a conductor. Though the *quantity of electricity* that flows is equal at all cross-sections, the electromotive force is by no means the same at all points along the conductor. It suffers a loss, or drop, of electrical potential in the direction in which the current is flowing, and it is this

difference of electrical potential that causes the electricity to flow against the resistance of the conductor. *Ohm's law* not only gives the strength of the current in a closed circuit, but also the *difference of potential* in volts along that circuit. The difference of potential (e) in volts between any two points along a circuit is equal to the product of the strength of the current (C) in amperes and the resistance (R) in ohms of that part of the circuit between those two points, or $e = CR$; e also represents the *loss* or *drop* of potential in volts between the two points. If any two of these quantities are known, the third can be readily found; for, by transposing,

$$C = \frac{e}{R} \text{ and } R = \frac{e}{C}.$$

EXAMPLE.—Fig. 438 represents part of a circuit in which a current of 3 amperes is flowing. The resistance from a to b is 1.5 ohms; from b to c is 2.3 ohms, and from c to d is 3.6 ohms.

Find the difference of potential between a and b , b and c , c and d , and between a and d .

SOLUTION.—Since $e = CR$, then,

The difference of potential between a and $b = 3 \times 1.5 = 4.5$ volts.

The difference of potential between b and $c = 3 \times 2.3 = 6.9$ volts.

The difference of potential between c and $d = 3 \times 3.6 = 10.8$ volts.

The difference of potential between a and $d = 4.5 + 6.9 + 10.8 = 22.2$ volts; or, in other words, the *loss*, or *drop*, of potential caused by a current of 3 amperes flowing between a and d is 22.2 volts.

1233. In a great many cases it is desirable to have the current flow from the source a long distance to feed lamps or motors, and return without causing an excessive drop, or loss, of potential in the conductors leading to and from the two places. In such circuits, the greater part of the total generated electromotive force is expended in those lamps or motors, and only a small fraction of it is lost in the rest of the circuit. Under these conditions, it is customary to decide upon a certain *drop*, or *loss*, of *potential* beforehand; and from that and the current calculate the resistance of the two conductors; for $R = \frac{e}{C}$.

EXAMPLE.—It is desired to transmit a current of 5 amperes to a motor situated 500 feet from the source; the total generated E. M. F. is 120 volts, and only $\frac{1}{10}$ of this potential is to be lost in the conductors leading to and from the motor. (a) Find the resistance of the two conductors, and (b) the resistance per foot of the conductors, assuming each to be 500 feet long.

SOLUTION.—(a) $\frac{1}{10}$ of 120 volts = 12 volts, which represents the *drop*, or *loss*, of potential on the two conductors. Let $e = 12$ volts; $C = 5$ amperes, and $R =$ the total resistance of the two conductors. Then,

$$R = \frac{e}{C} = \frac{12}{5} = 2.4 \text{ ohms. Ans.}$$

(b) The resistance per foot of any conductor is found by dividing the total resistance of a conductor by its length in feet; hence, since 2.4 ohms is the resistance of two conductors, each 500 feet long, then the resistance per foot of the conductors = $\frac{2.4}{2 \times 500} = .0024' \text{ ohm. Ans.}$

WIRING FOR INCANDESCENT LIGHTS.

1234. In Art. 1219, reference was made to two methods of current generation, namely, by means of batteries and dynamo-electric machinery. For electric lighting, the only practical method is the latter. Current is generated by revolving coils of insulated wire, mounted on an iron core and suitably connected together, in front of powerful electro-magnets. The power for this purpose is supplied by a steam engine, or, in some cases, by turbines, when steady water-power is available. The current is led to the place of utilization, or the distributing center, by means of heavy copper cables covered with some insulating substance, such as gutta-percha or rubber, to prevent electrical contact with the supports or other bodies which they may approach. These two materials are most commonly employed for the insulating covering of electric wires, being flexible and water-proof. Other insulators are paper, oils, porcelain, wood, silk, cotton, shellac, ebonite or hard rubber, paraffin, mica, glass, and dry air.

CONDUCTORS.

1235. Conducting cables, or wires, for any system of electric house-lighting are always arranged as a closed circuit; that is, one wire must be provided to convey the cur-

rent to the lamps, and another one to allow it to flow back to the starting point. It is not, however, necessary to provide one set of wires for each lamp for the entire distance. The arrangement should be somewhat like the trunk and branches of a tree. Heavy wires carry the whole current for the house up to the first distributing point, and wires continually branch out, becoming smaller at each such division. The name "lead"—pronounced *leed*—is frequently given to the conductors in a house.

1236. Electric-light conductors for inside wiring are of two descriptions—solid and stranded. The heavy conductors, which carry the whole current to a distributing center, are called **feeders**, and are usually made of stranded wire for the sake of flexibility; that is, they are composed of a large number of interwoven wires of small diameter. Fig. 439 shows the construction of such a cable.

The wires *w* project at the end, the insulation being all removed; a thin sheet of rubber *r* is first laid over, then a gutta-percha compound *g*, and over this a covering of braid *b* as a mechanical protection. For smaller conductors, such as mains or sub-mains, a solid wire may be used for the core, the insulation being of the same description. For connection to single lamps, a double flexible conductor is used, such as *A* or *B*, Fig. 440. The core of each is formed of



FIG. 439.



FIG. 440.

many fine wires *w* insulated with rubber and braided. These two sets of conductors are then twisted together, and

may be used to suspend the lamp, or they may be laid side by side and braided together.

1237. When it is necessary to make joints between wires, it is important to remember that the work can not be too well done. Under no circumstances should a joint be left unsoldered. When connecting a branch line to the main, the insulation is cut away as shown in Fig. 441; the

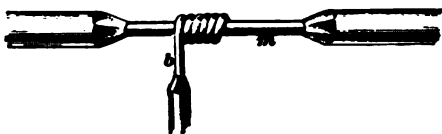


FIG. 441.

cut should not be made straight down towards the wire with the edge of the knife, forming a sharp shoulder on the insulation,

as the knife is very likely to make a nick in the wire, and subsequent bending might produce a crack at this point. Such a fault would increase the resistance locally, and cause heating, and, possibly, fire risk. In the illustration, the branch wire *b*, after being carefully bared of insulation and scraped clean with sandpaper, is shown wrapped over the the main *m* similarly exposed. This operation should be done with a pair of pliers of convenient size, and the turns of *b* should be close together. The joint should then be soldered, no acid being used, but resin only, as a flux, the reason being that it is impossible to clean off all the acid after the joint is finished, as some remains in the crevices and will eventually corrode the wire and break the electrical circuit. When the joint is cool, the wire is held firmly by the solder; all the exposed wire should then be covered by wrapping rubber insulating tape carefully over it, continuing across a short distance on the main insulation. When, however, the outer covering is braided, this should never



FIG. 442.

extend into the insulation of the joint; as, when exposed to dampness, the moisture is likely to penetrate and cause trouble. It may here be remarked that it is not so easy to

make a resin joint as one on which acid is used, which explains the disfavor in which the former is usually held by poor workers. Acid removes grease from the wire, such as a careless workman may have smeared on from his fingers,

but when the wire is not handled after cleaning, resin will make a good joint. An alternative method is to tin both wires before wrapping, using acid as a flux; then wipe carefully, cleaning thoroughly, to remove all trace of acid, and wrap over, using pliers to bend the wire. The joint should then be completed, with resin as a flux. When two wires are to be connected together to form a continuous conductor, the Western Union joint, Fig. 442, is employed, the wires being twisted one over the other, soldered, and taped.

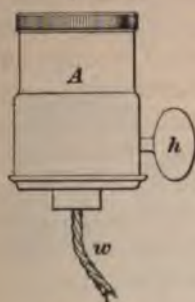
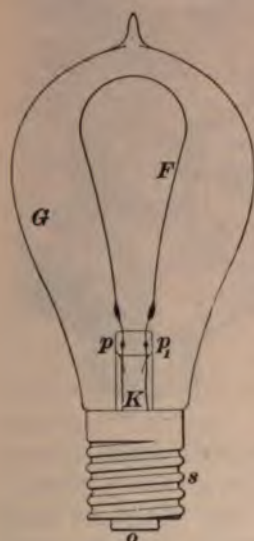


FIG. 443.

HOUSE FIXTURES.

1238. The **incandescent lamp**, Fig. 443, is provided with a composite base, made to fit in a corresponding socket connected with the house-wiring. The filament *F* is made of a thread of carbon, which material has a very high resistance. When enclosed in a vessel from which the air has been removed, and a current passed through the filament, it gives out light. Connections are

made, as shown by the dotted lines, from one end of the filament to the outside metallic screw sheathing *s*, and from the other end to the brass plug *o* at the bottom. The socket, Fig. 444, has a screw shell *s* inside, large enough to receive the base of the lamp, and at its center an insulated

tongue *t*, which presses against the plug on the lamp when the latter is screwed in. The wires supplying current are connected, one to the tongue *t* by means of the screw *a* at its lower end, the other to a similar screw (not shown) on the lower contact strip *c*. When the key *k* is turned into the vertical position, as drawn, the bridge *b* completes the circuit between the strip

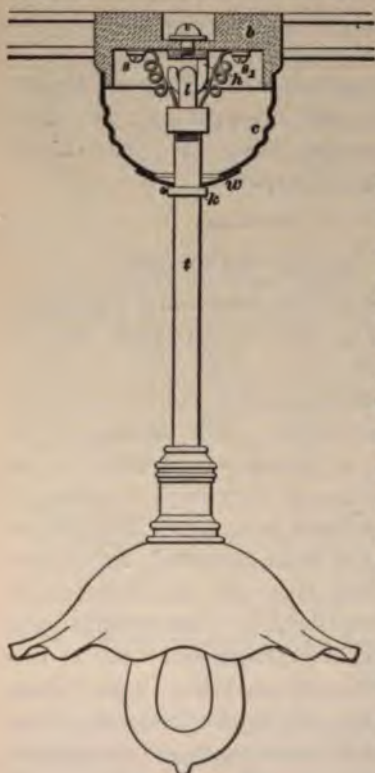


FIG. 445.

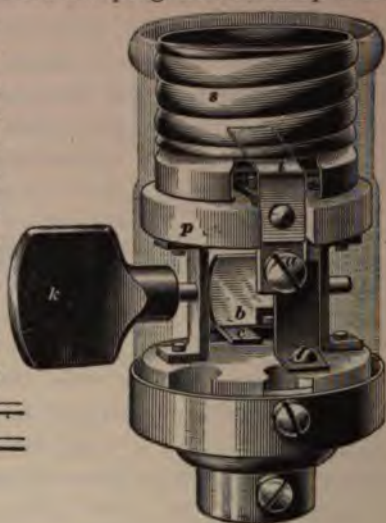


FIG. 444.

c and the sheathing *s*, pressing against a contact piece on the lower side of the porcelain plate *p*, which is in electrical connection with *s*. When the key is turned through 90°, the contact between *c* and *s* is broken, and the light is extinguished. The socket may be suspended from a flexible cord (*A*, Fig. 440) attached to a ceiling rosette or fixed to a bracket or electrolier.

1239. A **rosette pendant** is shown in Fig. 445. The leads are brought to the screws *s*, *s*₁ on the insulating base *b*, and the fixture wires are also secured to the same

contact-blocks, and pass down inside the tube *t* to the lamp. A casing *c* fits up against the base, the opening at the lower end being larger than the tube, and closed by a washer *w* held by a collar *k*. The pendant is thus free to swing a certain amount, being supported on a hook *h* passing through a loop *l* on the tube. When flexible-cord suspension is used, a knot should be made in the cord inside the rosette, and also, if practicable, in the lamp socket, to prevent the weight coming on the connections.

1240. Combination fixtures for gas and electric light are frequently installed. The fixtures must in this case be insulated from the gas piping of the building, a joint being used such as is shown in Fig. 446, in which the two metallic unions *a* and *b* are separated from each other by an insulating cement *c*, and the whole joint further protected by a covering of hard rubber or similar material *d*. No soft rubber must be used in the construction. At the point where the wires approach the fixture,



FIG. 446.

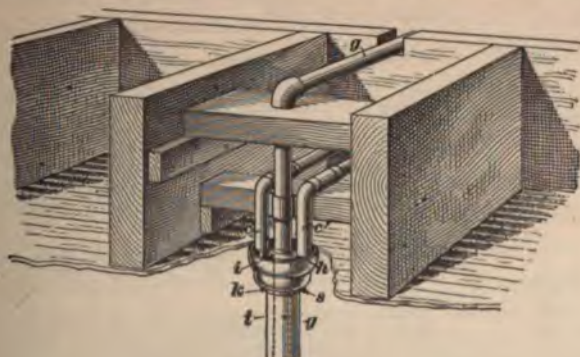


FIG. 447.

they must be kept clear of the grounded gas pipe, and the

outer shell at the point of entrance must be large enough to allow of this. In Fig. 447, the arrangement

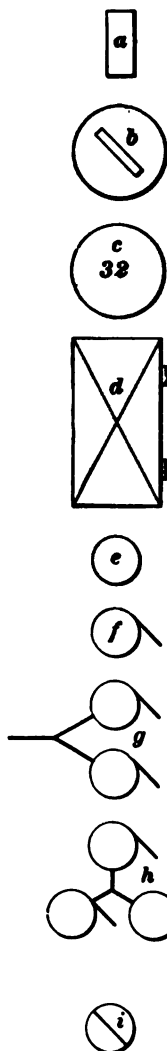


FIG. 448.

of wires is shown with relation to the piping for a chandelier. The gas pipe *g* is carried across between the floor-beams, and the insulating joint *i* is placed as already indicated, to form the connection. The wires are brought over in independent insulating conduits *c*, *c'*, as described in detail later, and inserted through the tube *t* surrounding the gas pipe *g*. There must be between these at least a quarter of an inch clear space, to conform with the insurance regulations. After the wires are in place, the hood *h* is pushed up against the ceiling, and secured by means of the collar *k* furnished with a set-screw *s*. It is necessary to examine carefully all edges of the metal shell, that any rough parts near the wires be smoothed down. The hood when in position must clear the wire, and not press it against the insulating joint; and, to guard against the entrance of moisture, the upper end of the fixture should be sealed.

SAFETY CUT-OUTS.

1241. In the diagrams of lighting circuits in the following pages, symbols as given in Fig. 448 will be used.

Symbol *a* is a safety plug, or cut-out.

Symbol *b* is a wall switch.

Symbol *c* is a thirty-two candle-power lamp.

Symbol *d* is a dynamo.

Symbol *e* is a sixteen candle-power lamp.

Symbol *f* is a sixteen candle-power lamp with a key socket.

Symbol *g* is a two-arm bracket with key sockets.

Symbol *h* is a three-light chandelier with key sockets.

Symbol *i* is a ten candle-power lamp.

1242. Safety cut-outs are devices that break a circuit before a wire becomes sufficiently heated by the passage of a current to cause danger of fire. They are also used to protect lamps. Fig. 449 shows an incandescent cut-out

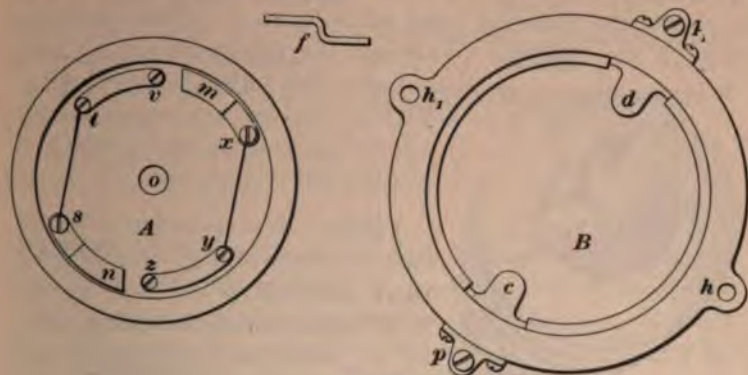


FIG. 449.

for small currents. It is called a rosette cut-out, and is principally used on ceilings where a lamp drops from the supply wires. The figure shows the inside view of the two halves. They are both composed of porcelain, upon which metallic connection pieces are screwed. The half *B* is screwed to the ceiling through the holes *h* and *h*₁. The ceiling, or supply wires, are respectively connected to the binding posts *p* and *p*₁, which are themselves connected to the two projecting elastic plates of metal *c* and *d*.

The half *A* has two projecting metallic pieces *m* and *n*, which hook in under *c* and *d*, and make the connections when the two halves are put together. The side view of *m* or *n* is given at *f*. Upon each of these pieces at the end that rests against the porcelain is a binding screw *s* or *x*. Two small metallic plates, each carrying a pair of binding screws *l* and *v*, or *z* and *y*, are screwed upon the porcelain at diametrically opposite points, and the lamp conductors

entering at hole *o* are connected respectively to *v* and *z*. If flexible cord is used, it should be knotted as already explained, Art. 1239, to sustain the weight of the lamp. Between the two binding screws *t* and *s*, as well as between *x* and *y*, are respectively connected two strips of a fusible alloy. This alloy melts and breaks the circuit when the current increases above a given value.

The current starts from one supply wire and flows through *d*, *m*, and the alloy, or fuse, wire *x y* to *z*. Then, it flows through the lamp to *v*, through the fuse wire *t s* to *c*, and out to the other supply wire.

The two halves are connected by a screwing motion which rubs the contact pieces together.

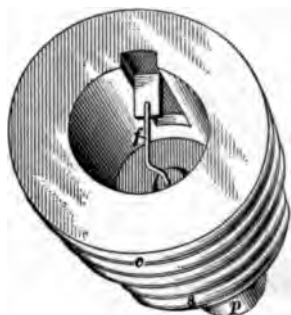


FIG. 450.

1243. A convenient form of fuse is shown in Fig. 450, called a **plug cut-out**, which is intended to be screwed into a socket similar to that used for lamps, and may be employed on branch circuits which do not carry a heavy

current. The screw sheathing *s* and plug end *p* are insulated from each other, except when joined by the fuse wire *f* which is soldered between them. A brass cap is screwed on the larger end of the plug at *c* to protect the fuse.

1244. The ordinary form of detachable fuse is shown in Fig. 451. The contact pieces *a* and *b* are made of sheet copper, and are intended to be clamped by screws to the cable tips, or terminals, at the distributing boxes or closets where the different circuits branch off. A strip *c* of fusible lead alloy is soldered to each contact piece, its cross-section being proportional to the maximum current to be carried, which is stamped on the copper ends.

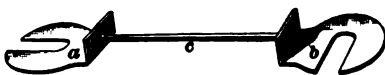


FIG. 451.

1245. A good form of connection between the mains and a branch circuit is illustrated in Fig. 452. This is known as a **branch block**.

The mains may be connected at m, m' ; the wires passing under the projecting ledges l, l' and the branch wires are secured at e, e' . The fuses are held between the screws a and b , c and d . To prevent damage when a fuse "blows," or melts, a porcelain cover is fitted over the face of the block.



FIG. 452.

1246. For the large currents of feeders, or mains, a double porcelain fuse block, as in Fig. 453, is used, the

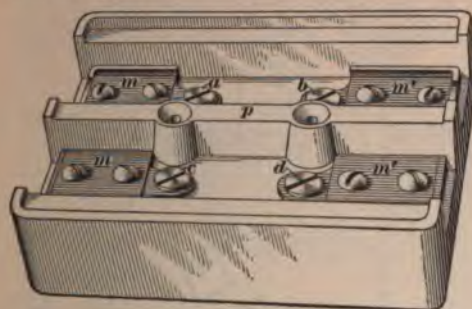


FIG. 453.

wires from the point of supply being inserted at one end, as at m, m , and the line continued from the terminals m', m' , at the other end. The fuses are inserted between the screws a and b , and between c and d .

The two sides of the circuit are separated by the partition p , so that all danger of short-circuit is eliminated.

1247. As a guide to the carrying capacity of fuses, the following table may be consulted, but it is to be pointed out that the fusing current depends upon the particular proportion of the metals used in the alloy, and their selection; also on the length of fuse and the character of the terminals:

TABLE 44.

Diam. in Mils.	B. & S. Gauge (approx.).	Amperes.
.017	25	3
.020	24	4
.032	20	7
.042	18-17	10
.056	15	15
.065	14	18
.075	13-12	25
.085	12-11	28
.096	11-10	31
.111	9	36
.130	8	50
.150	7-6	70

SWITCHES.

1248. A **switch** is an appliance interposed in an electric circuit for the purpose of readily and without dan-

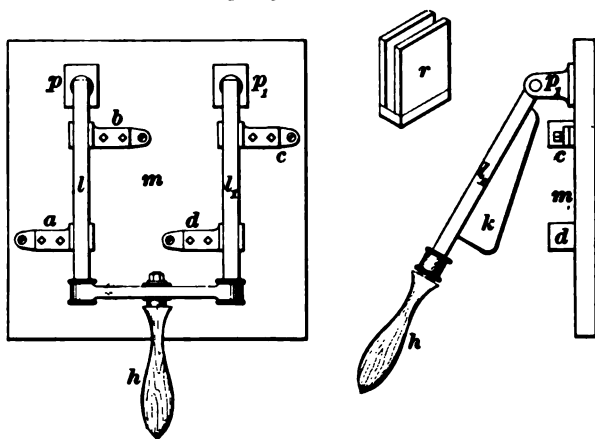


FIG. 454.

ger opening or closing that circuit. For large currents some form of knife switch, such as that shown in Fig. 454, is employed. The two copper levers l and l_1 carry plates of copper in the shape of knife blades, shown at k in the side

view. These knife blades fit between elastic metallic plates, shown in perspective at r . There are four pairs of these plates connected, respectively, to the metallic pieces a , b , c , and d , so that each knife blade connects with two pairs. The levers are pivoted at p and p_1 , and are moved by the handle h .

The line wires are both cut, and the ends of one connected, respectively, to a and b , while the ends of the other are connected to c and d . It will now be seen that when handle h is pushed down, the circuit is complete; but when h is pulled up, the circuit is broken in both wires. The base is of slate and is shown at m .

1249. Plug switches are frequently used for the connection between the house-wiring and the street mains. This switch consists simply of a conical metal plug p , Fig. 455, with a wooden knob k for a handle, and is pressed

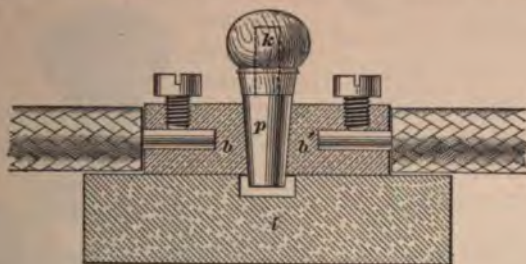


FIG. 455.

into contact with two blocks b , b' , forming part of the conductor circuit, and mounted on an insulating base i secured to the wall.

1250. A form of double-pole switch for currents up to 50 amperes is shown in Fig. 456. The positive and negative leads are brought up through the hole in the base b , and connected one to each of the terminals shown, by means of the screws s , s' . The leads for the lamps are connected in a similar manner to corresponding terminals on the other side of the switch, and the circuit is completed by forcing the arm a into contact with these terminals, thereby bridging

over the gap between them. The rubber knob *k* is fastened

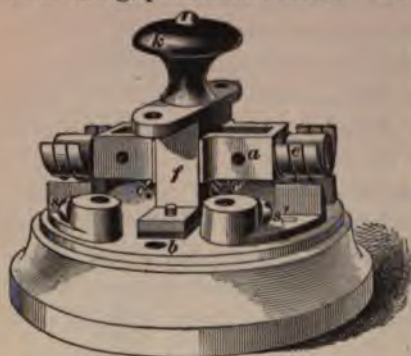


FIG. 456.

to a pin passing vertically through the frame *f* and secured to the springs *c*, *c'* at the lower end in such a way as to form a toggle-joint. When the knob is drawn upwards, the springs are compressed, and, on passing the center, they suddenly force the contact arm downwards.

In like manner, on pressing the knob down, contact is again broken.

1251. Fig. 457 shows a double-pole switch for small currents. It is usually fastened to the wall, the screws passing through the base.

The cylinder *c*, made of china or other insulating substance, has brass contact plates *p* on opposite sides, against which press brass or copper springs when the cylinder is in the position indicated in the cut. Four terminals are provided, lettered *a*, *b*, *c*, *d*, and the wires for connection to them are brought up through the holes in the base, one of which is visible.

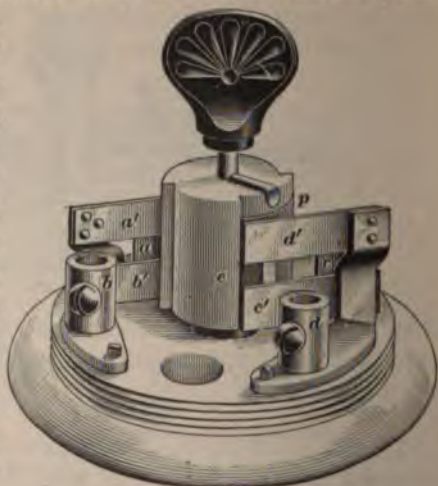


FIG. 457.

The incoming wires, positive and negative, are connected to the terminals *b* and *d*, and the outgoing wires to *a* and *c*. The springs *a'*, *b'*, *c'*, *d'* are riveted to the terminals *a*, *b*, *c*, *d*, respectively, so that when the switch is turned to the position shown, the circuit is

completed between terminals *a* and *b*, and between *c* and *d*. A quarter-turn breaks the contact, for the springs then rest only on the china cylinder. A screw cover is provided to enclose the body of the switch, the handle alone projecting.

1252. A single-pole switch may only be used for a few lamps, as, for instance, an electrolier or the lights in a small room. In Fig. 458 the lead is brought to the screw terminal marked *a*, and the wire from the lamps is secured to *b*, the return current passing through the other lead, which is connected directly to the main. When the key *k* is turned through 90°, the spring *s* is pressed against the tongue *t*, completing the circuit between *a* and *b*. Another quarter-turn releases the spring and extinguishes the lights. The wires are brought to the contacts through a hole *h* in the base, and a cover is fitted over, as in the case of the last-mentioned switch.



FIG. 458.



FIG. 459.

1253. Flush switches are so called because they are intended to be let into the wall, hardly projecting beyond the surface. The mechanism is usually of the same style as that in Fig. 457 or Fig. 458, but the cover is simply a plate, and the body of the switch is concealed. Another form is given in Fig. 459, called a **flush double push**

switch. This is a single pole switch, and is operated by pressing one or the other button, one being out when the other is in. The contact lever is *l*, which is forced between the brass leaves *c*, *c'* by means of a spring and toggle-joint, somewhat as in Fig. 456. One wire is wound around the screw *s*, and is held under the washer, and the other wire is secured in a similar manner on the other side. These two ends of wire belong to the same lead, which is cut at the point where the switch is to be inserted. The interior of the switch is protected by plates which are fitted over the sides.

The external appearance of the usual form of flush switch is simply a nicked brass plate on a wooden block let into the wall, a recess being provided in the plate for the key, which, therefore, projects only a slight distance from the level of the plate.

1254. When connecting up switches, great care must be taken to enter the wires at the correct terminals, and the path of the current should be traced through, in order to be sure that the closing of the switch will not short-circuit the system.

CONNECTIONS FOR INCANDESCENT LAMPS.

1255. There are three methods in general use by which electric incandescent lamps are connected in circuit, namely, the *multiple-arc*, or *parallel*, system, the *multiple-series* system, and the *three-wire* system.

Multiple-Arc System.—Fig. 460 shows the multiple-arc system, where the minus conductor *a b* and the plus

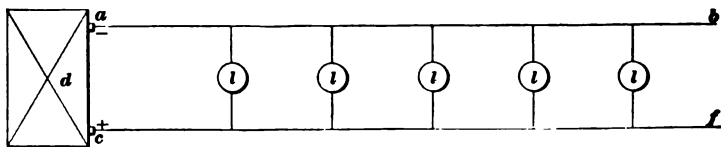


FIG. 460.

conductor *c f* supply current to the lamps from the constant-potential dynamo *d*. The lamps *I*, *I*, etc., are connected in parallel between the two conductors, and the amount of

current to be furnished depends directly upon the number of lamps used. Each lamp is entirely independent of all the others, and its extinction does not affect the brightness of the rest.

The lamps used in this system should all be of the same working voltage, and equal to that maintained between the two conductors. If the E. M. F. between these is 110 volts, only 110-volt lamps must be used.

1256. Multiple-Series System.—Fig. 461 shows the multiple-series system. Two or more lamps are arranged

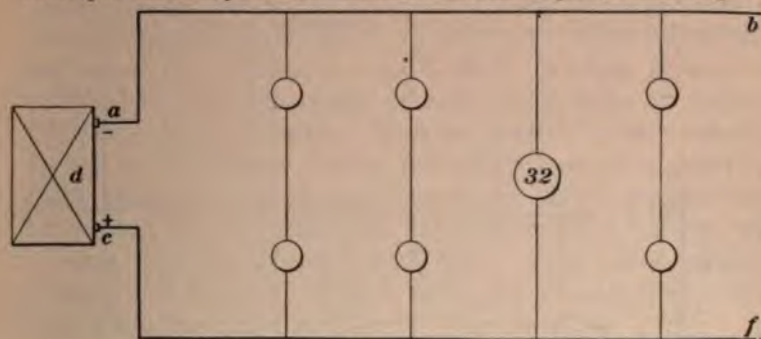


FIG. 461.

in series groups, and these groups are connected in parallel between the conductors *a b* and *c f*. Manifestly, when one lamp is burned out, all the other lamps in that group will also cease to glow. To obviate this difficulty, automatic devices which close the circuit across the lamps have been used, but have not given complete satisfaction. A diagram of one of these devices is shown in Fig. 462. The lamp is *l*, *m* is an electro-magnet in series with the lamp, and *a* is a lever carrying an armature which is attracted by the electro-magnet. When the current flows through the lamp, the electro-magnet is energized, and the lever *a* is held up tightly against its stop *e*. When, however, the lamp is burned out or the filament is destroyed from any cause, the

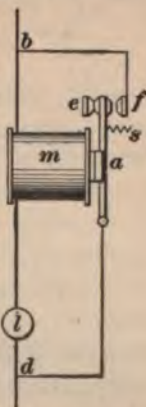


FIG. 462.

magnet releases its armature, which is pulled by a spring s against the contact f . The circuit is thus closed around $b f a d$.

If there be 200 volts pressure between the conductors, one 200-volt lamp, two 100-volt, or four 50-volt lamps may be connected across.

This system, on account of its adaptability to lamps of different voltages and candle powers, is occasionally used to light stores or large buildings.

1257. Three-Wire System.—Fig. 463 shows the three-wire system. The two dynamos d and d_1 are con-

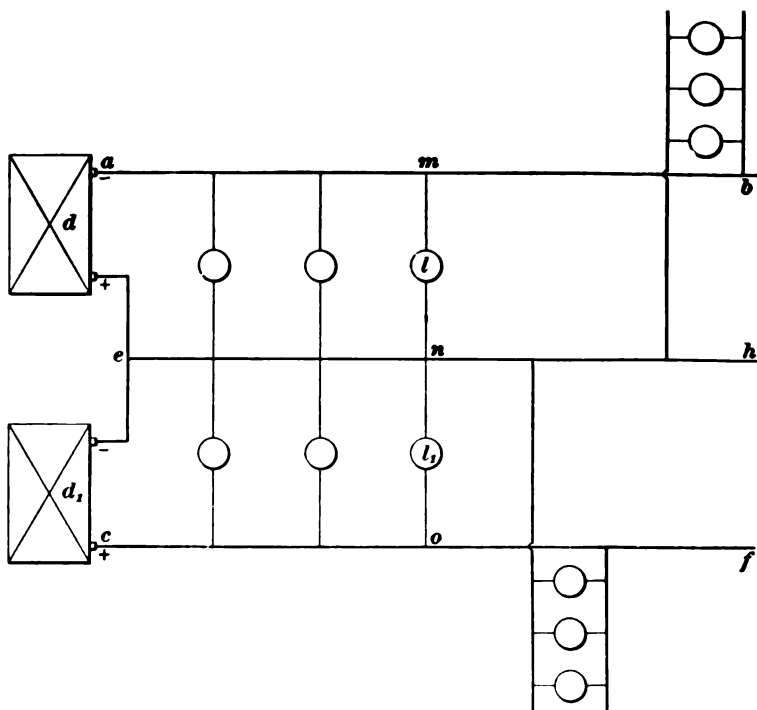


FIG. 463.

nected in series, the positive lead of one being joined to the negative lead of the other. From the remaining terminals of the machines, the main leads $a b$ and $c f$ are brought out,

and the third, or neutral, wire e h is connected to the short lead, already mentioned, which joins the two dynamos. The lamps are connected between this neutral conductor and either of the outer mains. It is, therefore, necessary that the E. M. F. of each dynamo should be the same; the lamps of one voltage may be used throughout. When, as in the figure, there is an equal number of lamps on each side of the system, it will be observed that no current will pass through the neutral wire. Considering the outer wires as the main conductors, this becomes a 200-volt system, if the lamps used are for 100 volts; for each of them, such as l and l_1 , would require an E. M. F. of 100 volts at its terminals, m, n and n, o , making a total E. M. F. between m and o of 200 volts. The advantage of such an increase in voltage will be pointed out later. It is not possible to have the two sides of the system always perfectly balanced in practice, and when the current required for one side is greater than that used on the other side, the difference in amount will return by way of the third wire. This extra current changes in direction of flow, according as one side or the other has the larger number of lamps burning.

It will be seen that the three-wire system is quite like the multiple-series with groups of two lamps. There is, however, the important difference that when a lamp on a three-wire system burns out or is switched off, none of the remaining lamps are affected.

1258. Flexible Two-Wire System.—For a local installation the three-wire system is not a good choice, as two dynamos must be constantly running; but when there is a three-wire city supply available, a combination wiring for the two systems may be put in, the private plant or the city mains being used as may be convenient. This arrangement is known as the **flexible two-wire system**, and is almost identical with the three-wire system, the only difference being that the neutral wire N , Fig. 464, is made double the size, in sectional area, of each of the outer wires. When used on the two-wire multiple-arc system, the connection to

the street mains m, m, m , is broken, and the two outer leads are joined together and to one terminal of the dynamo in the building, and the middle wire to the other terminal. This may be accomplished by means of a special switch S , as shown in the figure. The upper contact-blocks 1, 2, 3 are connected to the street mains, and the lower two, 4 and 5, are joined together by a copper bar c . The central contacts 6, 7, 8 are connected to the three blades of the switch, which are insulated from each other. When the switch is

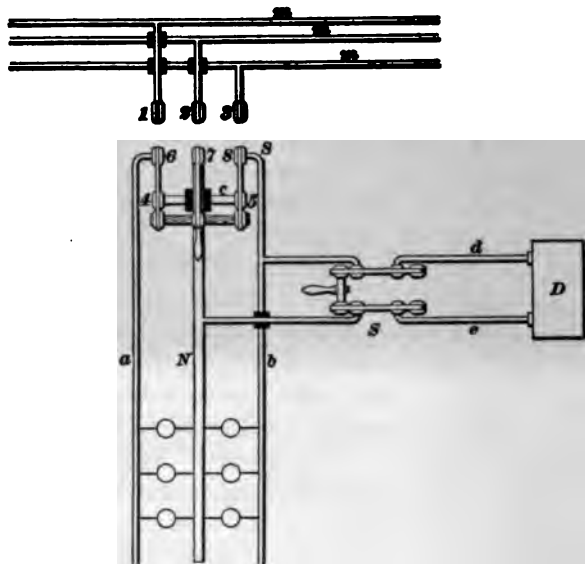


FIG. 464.

thrown upwards, the mains a, N, b are put in communication with the street mains m, m, m ; when it is thrown downwards, the outer mains a, b are joined together through the circuit 6-4-5-8; and, the switch S' being closed, the leads d, e from the dynamo D supply current to the lamps throughout the whole system, the heavy wire N acting as a return path for the current passing through the two outer mains a, b .

1259. There is an important consideration to be remembered as regards the E. M. F. of the dynamo. If

lamps taking 110 volts are used, the E. M. F. across the mains a, b for the three-wire system will be 220 volts. If the drop of potential (Art. 1232) be 5 per cent. from street mains to lamps, there will be a loss at full load of about 11.5 volts, being 5.75 volts in each main a and b , the neutral wire taking no current. On changing over to the two-wire system, there will be the same percentage of loss in each of the mains a and b , and an equal loss in the return wire N , being a total drop of 11.5 volts. Therefore, the dynamo must furnish an E. M. F. of $110 + 11.5 = 121.5$ volts, although the pressure on each side of the three-wire system, at the street mains, is only $110 + 5.75 = 115.75$ volts. In this case, however, the neutral wire carries practically no current, the drop being confined to the outer mains.

METHODS OF WIRING.

1260. Feeders and Mains.—**Feeders** are conductors supplying current to single terminal points or distributing centers, running directly from the source of current to those points without any branches or other connections throughout their length.

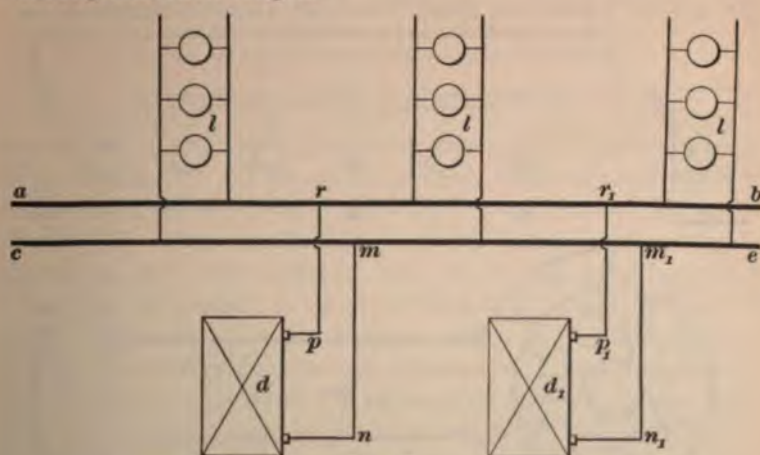


FIG. 465.

Mains are conductors which are tapped at many points for supply of current to branch circuits. In Fig. 465 the

heavy lines $a b, c e$ are the mains, and $m n, r p, m_1 n_1, r_1 p_1$ are the feeders extending from the dynamos d, d_1 to the mains. These latter are tapped at any desired points for the branch circuits l, l, l .

1261. There must always be some drop in potential along the conductors, as has already been pointed out, but it is of the utmost importance that the drop from the dynamo or street mains to the lamps at any point of the system should be uniform, so that all the lamps may burn at the same degree of brilliancy. If the drop to one set of lamps were 2 volts, and to another set 5 volts, then when the first was burning brightly, the second would be 3 volts below its required voltage, and the lamps would appear quite dim. The amount of drop usually allowed is about five per cent., and this is divided over the feeders and mains and branches according to their length, or as special conditions may warrant.

1262. Connections for equalizing the E. M. F.

Loop Circuits.—Fig. 466 shows two methods of preserving equal E. M. F.'s. at all points. At (v) is shown a loop circuit, in which the drop from the dynamo-terminals to

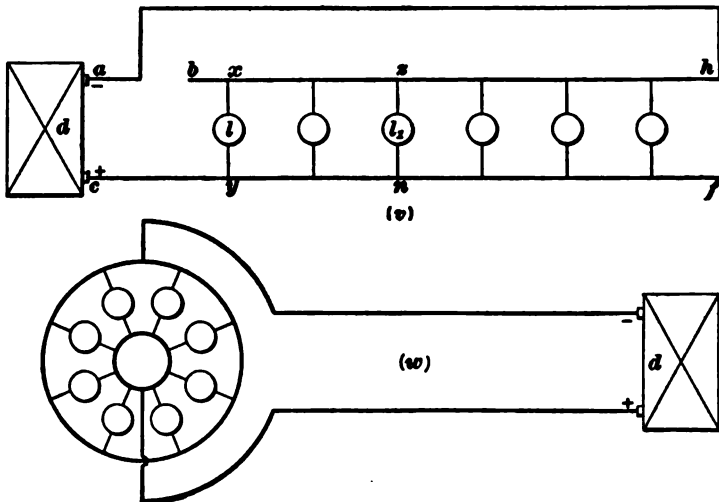


FIG. 466.

any lamp is the same. It will be seen that the length of circuit through $c y x h a$ for the lamp l is equal to that through $c n z h a$ for the lamp l_1 , so that all will burn with equal brightness. A closed loop circuit is shown at (w), one feeder from the dynamo d being connected to the inner ring and one to the outer ring. It will be understood that this is diagrammatic only, for in practice these two circles would be of the same diameter, insulated from each other, of course, the lamp leads being connected on all round at the required points.

1263. Tap circuits are those wires making actual connection to the lamps from the sub-mains. There are

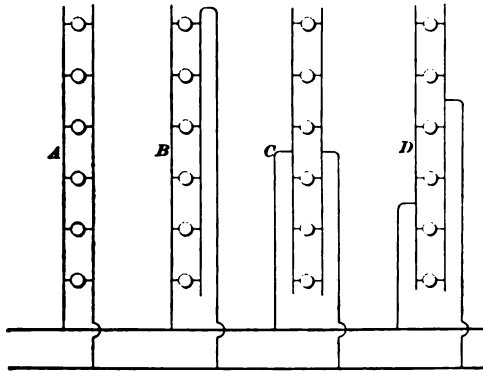


FIG. 467.

several methods of arranging these wires, the simplest being as in *A*, Fig. 467. This may, however, result in the further lamps burning quite dimly, if there are a number on the circuit. A better method is *B*, which bears some resemblance to the loop system, and is a very good way of arranging the leads. A third method is *C*, which is like a feeder and main on a small scale, and *D* is a modification which gives better distribution of pressure. The first mentioned may be used when the number of lights is small, and that marked *C* for double the number, since the connection is at the middle. In small tap circuits it is not usual to allow for any drop of potential, since the wires are short and the loss insignificant.

1264. There are, broadly, two systems of house-wiring, the *tree system* and the *closet, or cabinet, system*.

The **tree system** is illustrated in Fig. 468. The general distribution of wires is somewhat similar to the trunk and branches of a tree, hence the name. The mains *a b*, *c f* are

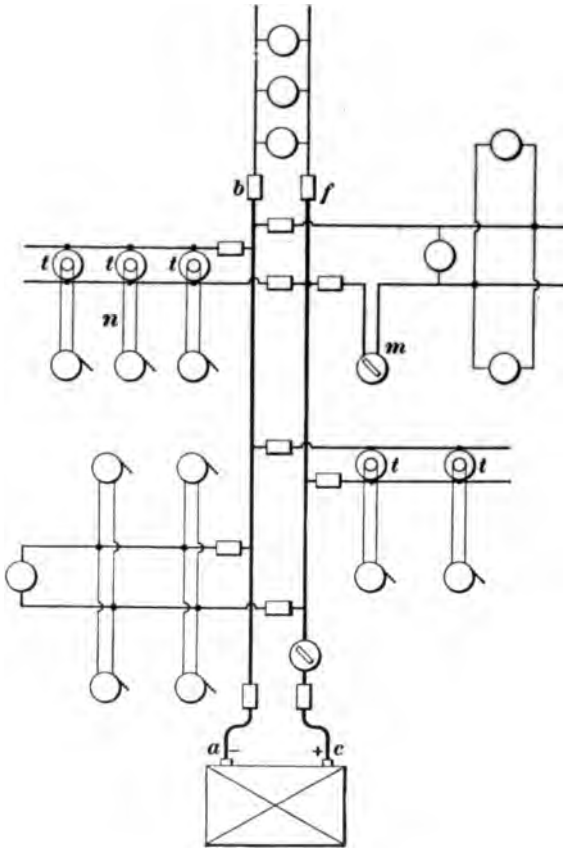


FIG. 468.

carried through the building, being heavier at the lower end which carries the entire current. If, however, the mains are only of moderate length, they may be of equal size throughout. In the tap circuits the rosette cut-outs *t*, *t*, etc., are similar to that shown in Fig. 449, lamps with

key sockets being attached. When keyless sockets are used, a switch such as *m* is placed in some convenient position.

1265. The **closet system**, shown in Fig. 469, is more generally used than the tree system. Separate feeders are

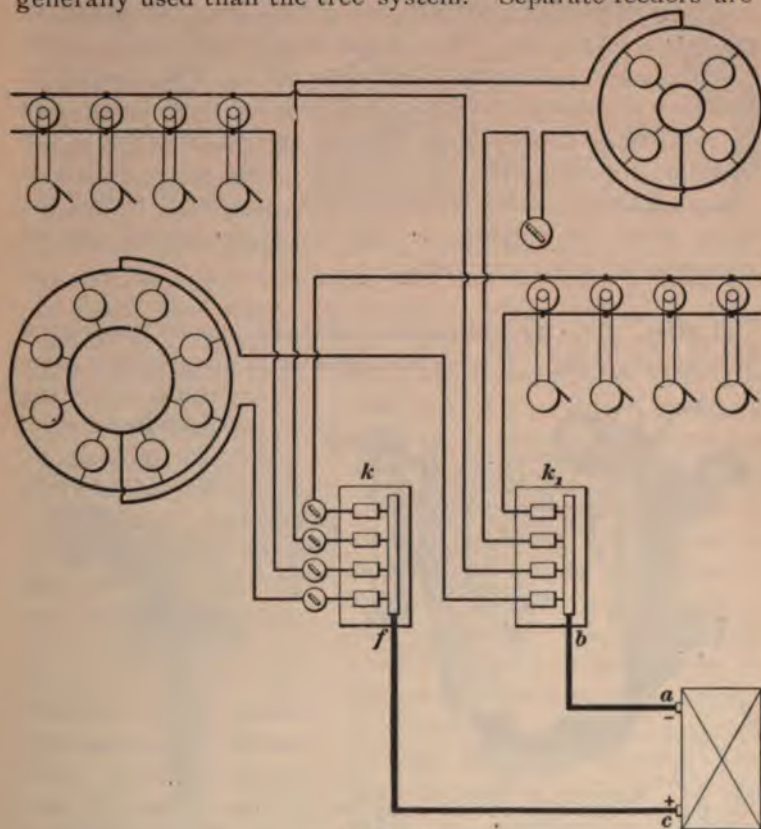


FIG. 469.

run to various distributing centers, and from these points the smaller, or tap, circuits start. The feeders in the diagram are *ab* and *cf*, making connection between the dynamo and the closets *k* and *k₁*. In these closets the wires to each group of lamps are branched off. The two distributing boards may both be arranged in one closet, unless there is a considerable number of circuits, making a double closet

desirable. They are usually lined with asbestos, and painted outside with insulating paint. Cut-outs are always connected where a conductor branches off, and frequently in the leads of each lamp. On entering the closet, the leads are generally separated into two groups, one consisting of the positive and the other of the negative wires, in order to reduce the possibility of short-circuits. The placing of switches is subject to convenience, one or more being used to control the lamps for each room, and main switches are installed for each floor of a house. One large switch is always located at the dynamo or at the point where the wires enter the building, so that the whole system may be disconnected when required.

1266. The **transformer system** is sometimes used in house-lighting. The **transformer** is a stationary piece

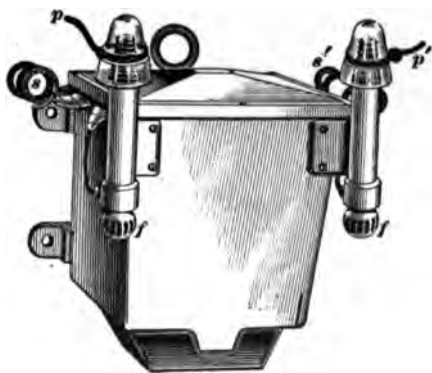


FIG. 470.

of apparatus consisting of two insulated coils of wire, surrounded by a mass of iron, the whole enclosed in an iron water-proof case, Fig. 470. The insurance regulations require that the transformer be placed outside the house, and it is usually bolted to the outer wall or carried on a near-

by pole. The current is supplied to one of the coils at a pressure of perhaps 2,500 volts, and the house current is taken from the terminals of the other coil, at a pressure suitable for the lamps. The first of these coils is called the **primary**, and the wires are shown at p, p' ; the other coil is the **secondary**, and its terminals are indicated by the letters s, s' . In this transformer, fusible cut-outs f, f are provided for the primary circuit, being inserted from the lower end of the cylindrical corner brackets on the case.

INTERIOR WIRING.

1267. There are three methods of running electric-light wires, namely, *cleat-work*, *molding*, and *concealed work*.

Cleat-work is used in such places where appearance is of little consequence, as in factories, and is the least expensive method of running wires.

Cleats are narrow strips of wood placed

at regular intervals along the wall or ceiling, arranged to hold the wires in position, clear of each other and of neighboring objects. Such a cleat is shown in Fig. 471.

It is made in two pieces, the lower *a* being a flat strip half an inch or more in thickness by about an inch in width and four inches long; the cap *b* has grooves across its lower surface to receive the wires, which must be separated at least $2\frac{1}{2}$ inches to conform to the requirements of the insurance companies. The cleat is secured to its support by means of screws passing through the holes *s, s*. Screw cleats, such as that illustrated in Fig. 472, may be used if desired. In this style of insulator, a porcelain

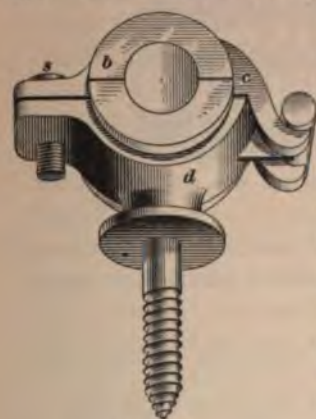


FIG. 472.

split bushing *b* is put over the wire and supported by a metal clamp in two pieces *c* and *d*, held together by a screw *s*. A wooden bushing is sometimes substituted for the porcelain, but does not provide such a reliable insulation.

1268. When a wire crosses another, and there is the full E. M. F. of the circuit between them, extra insulation is required, and a wrapping of rubber tape may be laid on,

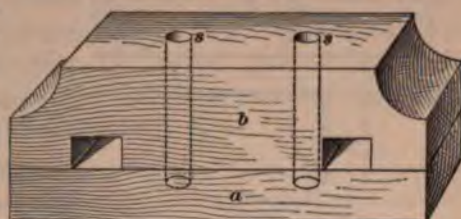


FIG. 471.

as indicated in Fig. 473 at *a* and *b*. The cleats *c* and *d* have three notches in them to receive the three main leads, and are correspondingly larger than the two-wire cleats.

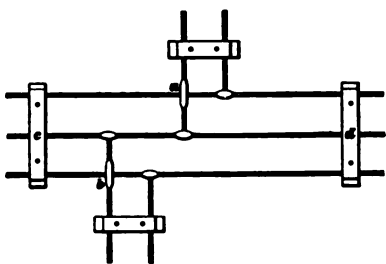


FIG. 473.

When the wires are to pass through a wall or partition, or wooden beams, they must be protected by insulating tubes of glass or porcelain, or some substance that will not support combustion, and so constructed that they will not pull out of place. Such a tube is shown in Fig. 474; the thread on the body *b* enables the

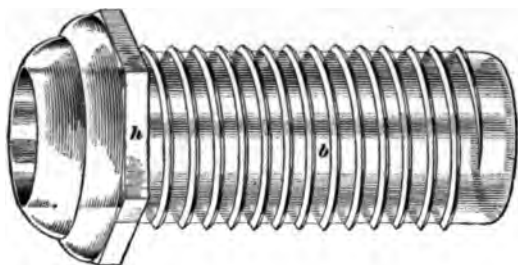


FIG. 474.

insulator to be screwed firmly into place by means of the hexagonal head *h*, which has a shoulder like a bolt head, and may be set up tightly.

1270. When the house-service wires are brought into the building direct from an overhead line, wall insulators of the type of Fig. 475 should be used. It will be noticed that the outer end projects downwards, and the bend thus given to the wire, called a **drip loop**, will cause the rain

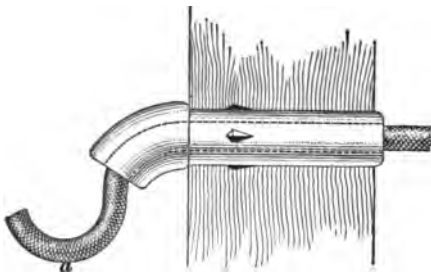


FIG. 475.

to fall off at *a*, which would otherwise creep along the wire into the house.

1271. In breweries, dye-houses, etc., the wires, being subject to dampness, must be separated at least six inches, and water-proof keyless sockets should be used for the lamps. In paper-mills, sawmills, etc., which present extra fire risks, no switches should be used. The smallest size of wire allowed for cleat work is No. 12 B. & S.

1272. Molded work is a style of wiring more ornamental than cleat work, and is generally used in houses in which no provision has been made for accommodation of the wires at the time of building. The molding is made of pine, cut into lengths of ten feet, and consists of two parts, one of which *b*, Fig. 476, is called the *base* or *mold*, and is provided with longitudinal grooves to hold the wires, and the other part *c* is called the *capping*, which is intended to hold the wires in place and present a finished exterior. For this reason the capping is usually ornamented to correspond with the decoration of the room. The base is screwed in position first, being held by the flat-head screws *s*, *s*, and the capping is then fitted over and secured by round-head brass screws *s'*; iron screws would not look well. Particular care should be taken that these screws do not touch the wires or damage the insulation, as a fault might thereby develop which would cause trouble or even fire risk. The wires, if positive and



FIG. 476.



FIG. 477.

negative, should be separated a distance of at least half an inch from each other. Molding must not be used in places where there is dampness, and should in every case have at least two coats of some water-proof paint, or be otherwise treated so as to be impervious to moisture.

1273. It is usually desirable to have molding arranged so as to be unnoticeable. It may frequently be set as a border to the wall paper, or used instead of picture molding, the hooks

being attached in the ordinary manner over the edge of the capping, Fig. 477. When molding is required at only one side of a room, and an unsymmetrical appearance is to be avoided, dummy molding, carrying no wires, may be employed to produce the desired effect.

1274. Concealed Work.—This is the most satisfactory method of wiring a building, and consists in providing a complete network of tubing, laid beneath the plaster of the walls, between partitions, and under floors, to receive the wires at any time and allow of their removal if necessary. Such a system of tubing is known as **interior**

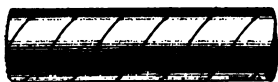


FIG. 478.

conduit. The tubing is made of papier-mache, which, by treatment with a bituminous solution, is rendered water-proof and insulating. In appearance it is like Fig. 478, and is made in all sizes from $\frac{1}{4}$ -inch inside diameter to $1\frac{1}{4}$ inches, in lengths of about ten feet. Joints are made by carefully smoothing the ends of two pieces so that they will make a close butt joint with no rough edges, and threading



FIG. 479.

them into a metal sleeve, which is then compressed into the tube by means of a special tool. The joint then appears as shown in Fig. 479. The conduit is also made with a sheet-brass covering, for protection against rats and mice. Another form is that of an iron tube with an insulating coat on the inside, and screwed joints between different lengths. Wires of opposite polarity may be placed in these iron-armored conduits, but the papier-mache tubes may contain only one wire each. The tubes are secured in place by metal staples or brass clips. A staple driver should be used for the former, to prevent damage to the tubing.

1275. To ensure the easy passage of the conductor, all corners are rounded, an elbow, Fig. 480, being employed for flexible wires, and for rigid conductors a **junction-box**,

as shown in Fig. 481. The ends of the tubes should project well into the box through the openings *o, o*, etc., and a thoroughly strong soldered joint be made between the wires, wrapped with insulating tape as a further precaution. When the tubes

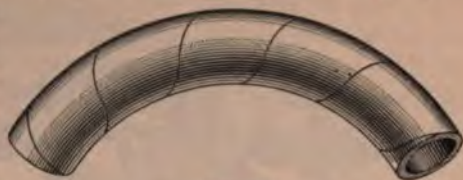


FIG. 480.

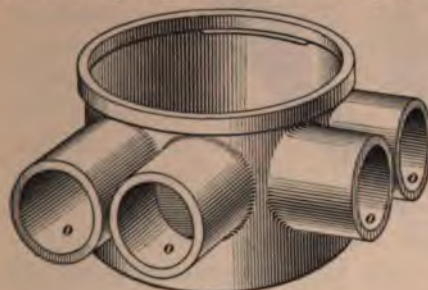


FIG. 481.

are all in position, a **fishing-wire** is pushed through from one outlet to another, the electric light wire is connected to the end, and pulled through.

1276. At the points where branch circuits start, junction-boxes, such as that shown in Fig. 482, are used. At each side are openings *m, m, m', m'* to take the main conduit-tubes, and smaller ones at *b, b, b', b'* for the branch tubes. A porcelain branch-block is introduced to carry the connections and cut-outs, as in similar cases already considered.



FIG. 482.

1277. Street Junction-Boxes.—When connection is made between the inside wiring and street main, a junction-box such as that illustrated in Fig. 483 is employed. The three-wire system will probably be used on account of the economy in copper so obtained. The three mains *a, b, c* pass straight through the box, but from the double terminals to which they are clamped are run the house leads *a', b', c'*. The whole set of couplings is enclosed in a cast-iron,

water-tight box fitted with a cover, and the wires for the

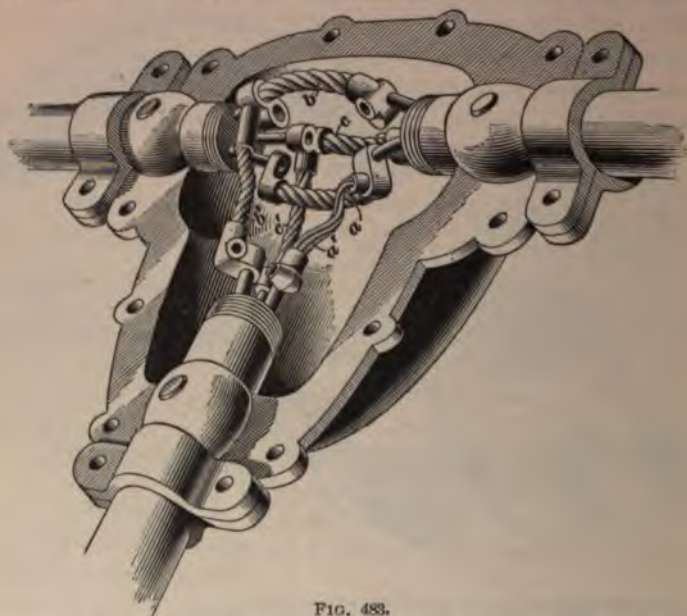


FIG. 483.

house service are protected by an iron pipe which extends from the junction-box to the cellar.

WIRING CALCULATIONS.

1278. The size of wire required to supply current to any group of lamps depends on the number of lamps, each of which takes a certain average current. The following table gives the value of this current for lamps of different candle power and with a line E. M. F. of 110 and 55 volts:

TABLE 45.

110 Volts.		55 Volts.
.5 amp.	16 c.p. lamp	1 amp.
1.0 amp.	32 c.p. lamp	2 amp.
1.5 amp.	50 c.p. lamp	3 amp.
3.0 amp.	100 c.p. lamp	6 amp.

Since the lamps are connected across the leads in multiple-arc (Art. 1221), whether on the two-wire or three-wire system, it is evident that the main conductors must be able to carry current for each lamp on the circuit. If the average current is .5 ampere, and there are 30 lamps on the circuit, the main conductors will have to carry $30 \times .5 = 15$ amperes.

1279. In nearly all cases a very simple formula may be used in calculating the size of wire to be furnished for any particular circuit. According to Ohm's law, the loss in volts divided by the current flowing gives the resistance of the line (Art. 1232); if this result be divided by the length of the line in feet, the resistance in ohms per foot is obtained, and the size of wire corresponding to this resistance can be found directly in a wire-table. Since resistances are usually given in ohms per thousand feet, owing to the low resistance of copper, it will be necessary to multiply by 1,000 to find the corresponding gauge of wire.

1280. We may express these operations in the shape of a formula as follows:

$$R_f = \frac{E}{CL}, \quad (1.)$$

where R_f is the resistance per foot of the wire, E the drop in volts, C the current, and L the length of the wire in feet.

We have seen, however (Art. 1278), that a 16 c.p. lamp on the usual 110-volt circuit takes .5 ampere. Then for C we may substitute the number of lamps N multiplied by the current required for one, or $N \times .5$. The total length of line L is also equal to $2 F$, when F is the distance in feet, as measured along the double line between the point of supply and the lamps. We may, therefore, write the foregoing formula as follows:

$$R_f = \frac{E}{.5 N \times 2 F} = \frac{E}{NF}. \quad (2.)$$

The term NF is the number of lamps multiplied by the distance from the source of current to those lamps; in other words, this expression gives the **lamp-feet**.

1281. From the preceding we may derive the following rule:

Rule.—*In order to find the resistance per foot of the conductor to use in any 110-volt circuit with 16 c.p. lamps, divide the loss in volts, as predetermined, by the lamp-feet.*

The corresponding wire may then be found from Table 43, as explained in Art. 1279.

EXAMPLE.—A group of 41 lamps, 16 c.p., is to be set 1,500 feet from the dynamo on a 110-volt circuit. What diameter of conductor should be used when the drop is to be 5 volts?

SOLUTION.—The number of lamps = 41 = N ; the distance in feet = 1,500 = F ; and the drop in volts = 5 = E . The lamps being of 16 candle power, and the voltage 110, formula 2, Art. 1280, gives the resistance per foot of the wire, and

$$R_f = \frac{5}{41 \times 1,500} = .0000818 \text{ ohm per foot} \\ = .0818 \text{ ohm per 1,000 feet.}$$

From the wire-table we find this corresponds to No. 00 B. & S. Ans.

1282. When there are other lamps on the circuit than 16 candle power, they should be allowed for in estimating the total number, as follows:

For one 32 c.p. lamp, count 2 of 16 c.p.

For one 50 c.p. lamp, count 3 of 16 c.p.

For one 100 c.p. lamp, count 6 of 16 c.p.

EXAMPLE.—An electrolier in a large hall is provided with one lamp of 100 candle power, four of 50 c.p., twelve of 32 c.p., and twenty-four of 16 c.p. What size wire will be required for the main conductors from the closet, the distance being 300 feet, the line voltage 110, and the drop 4 volts?

SOLUTION.—The number of lamps is to be expressed in terms of 16 c.p. lamps.

1 lamp of 100 c.p. = 6 of 16 c.p.

4 lamps of 50 c.p. = 12 of 16 c.p.

12 lamps of 32 c.p. = 24 of 16 c.p.

24 lamps of 16 c.p. = 24 of 16 c.p.

Total = 66 lamps = N .

The drop in volts = 4 = E , and the distance in feet = 300 = F . Then, by formula 2, Art. 1280, the resistance per foot of the wire,

$$R_f = \frac{4}{66 \times 300} = .000202 \text{ ohm} \\ = .202 \text{ ohm per 1,000 feet.}$$

Reference to Table 43 shows this to be almost exactly No. 3 wire, which should, therefore, be chosen. Ans.

1283. It is always necessary to compare the results obtained by these calculations with a table of carrying capacity, in order that undue heating of the conductors may be avoided. In the example just given, the current is $66 \times .5 = 33$ amperes, since each 16 c.p. lamp would take .5 ampere, and this is little more than one-half the allowable current for No. 3 wire, as shown in Table 43, so that this wire has a large margin of safety.

1284. In calculating the wire for lamps on a 55-volt circuit, formula 2, Art. 1280, is modified to read

$$R_f = \frac{E}{2 N F},$$

since the current used per lamp is doubled. The 16 c.p. lamp is taken as the standard, as before, its current being now 1 ampere, instead of .5 ampere.

EXAMPLE.—A room is provided with a cluster of 24 lamps of 16 candle power, and 8 of 32 candle power. The E. M. F. of the circuit is 55 volts, and the line loss from the closet is to be 3 volts, the distance being 75 feet. What size wire should be used?

SOLUTION.—The line loss is 3 volts = E ; the number of lamps is 24 of 16 c.p., and 8 of 32 c.p., equivalent to a total of $24 + 6 = 30$ of 16 c.p. = N ; the distance is 75 feet = F . Then, by the last formula, the resistance per foot,

$$R_f = \frac{3}{2 \times 30 \times 75} = .00067 \text{ ohm} \\ = .67 \text{ ohm per 1,000 feet.}$$

The corresponding wire is No. 8. The current in the circuit is $30 \times 1 = 30$ amperes; but, as the limiting current for this size of wire is 25 amperes, we must take the next size larger, and use No. 7. Ans.

1285. In such a case as the above, we might wish to know what the resulting drop will be, since we have to use a different size of wire. This is easily obtained by a reversal of formula, Art. 1284, for a 55-volt circuit.

$$E = R_f \times 2 N F = 2 R_f N F.$$

No. 7 wire has a resistance per 1,000 feet of .519 ohm, or

.000519 ohm per foot. N , as before, = 30, and F = 75. Then, the drop,

$$E = 2 \times .000519 \times 30 \times 75 = 2.33 \text{ volts.}$$

1286. In the same manner the drop may be found for a 110-volt circuit, when the size of wire, the number of lamps, and the distance are known, by a modification of formula 2, Art. 1280,

$$E = R_f N F.$$

EXAMPLE.—What will be the drop in a 110-volt circuit, in which is located a group of 15 lamps of 16 candle-power, the distance from the point of supply being 270 feet, and the wire No. 10 B. & S.?

SOLUTION.—The resistance per 1,000 feet of No. 10 wire = 1.04 ohms, or per foot = .00104 ohm = R_f . The number of 16 c.p. lamps is 15 = N , and the distance in feet = 270 = F . Then, by the formula just given, the drop E = $.00104 \times 15 \times 270$ = 4.2 volts. Ans.

1287. When, in calculating the wire for a lighting system, it is necessary to use a size of wire larger than that required for the given drop, the effect may be balanced by using a smaller wire than that called for in another part of the same circuit. Suppose, for instance, a total drop of 6 volts were allowed in a circuit composed of two different lines, and it were decided to provide for a drop of 2 volts in one part and 4 volts in the other. If, then, it were found that the wire to give 4 volts drop was too small to carry the current safely, and a larger wire had to be used, giving a drop of only $3\frac{1}{2}$ volts, the second wire could be designed to allow $2\frac{1}{2}$ instead of 2 volts drop, provided, of course, that the safe carrying capacity were not exceeded.

When the calculations call for a wire smaller than No. 14, it should not be used, as this size is the smallest allowed by the underwriters for interior wiring.

1288. In calculating the wire for a loop circuit, such as in Fig. 484, the total length of conductor is evidently $(4 \times 75) + (4 \times 20)$ = 380 feet, but the actual length traversed by the current for any one lamp, such as a , is $10 + 75 + 20 + 75 + 10$ = 190 feet for the double distance. If there are 40 lamps on the loop, the lamp-feet (Art. 1280) will be 40 times

one-half this double distance, or $40 \times 95 = 3,800$ lamp-feet, giving the same result as if the lamps were all bunched at the further end.

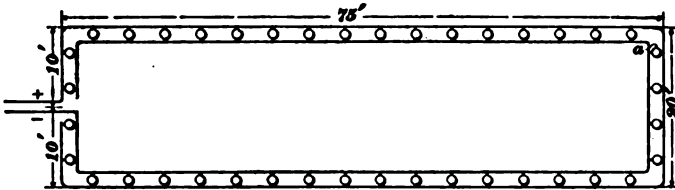


FIG. 484.

Rule.—*In determining the size of wire for a loop circuit, multiply the number of lamps by one-half the distance, in feet, around the loop. This will give the lamp-feet $N F$, and is used in the formulas already given.*

EXAMPLE.—What size wire is required for a loop circuit similar to Fig. 484, having 26 lamps, 110 volt, 16 c.p., the length of the room being 80 feet, and the width 30 feet? Allow for 3 volts drop.

SOLUTION.—The total length of circuit through any one lamp is $(2 \times 80) + (2 \times 30) = 220$ feet, and the single distance is $\frac{220}{2} = 110$ feet = F . The number of lamps is $26 = N$, and the allowable drop is 3 volts = E . Then, since 16 c.p. lamps are installed, and the E. M. F. of the circuit is 110 volts, the resistance per foot of the conductor will be, by formula 2, Art. 1280,

$$R_f = \frac{3}{26 \times 110} = .00105 \text{ ohm} \\ = 1.05 \text{ ohms per 1,000 feet.}$$

By reference to the wire table, it will be seen that this corresponds almost exactly to No. 10 wire. The current is $26 \times .5 = 13$ amperes, which is within the safe limit, and No. 10 wire will be used. Ans.

1289. Heavy Conductors.—It frequently happens that a very large wire is necessary for a feeder, and the resistance is not given in the wire tables, so that the formulas already considered will not apply. In this case, the area of the wire in circular mils (Art. 1226) is calculated by the following formula, for 110-volt circuits:

$$A = \frac{10.8 N F}{E},$$

in which N , F , and E have the same significance as in the preceding formulas.

EXAMPLE.—The feeders from the switchboard to the distributing center in a certain installation are 160 feet in length, and carry the current for 600 sixteen candle-power 110-volt lamps, a drop of 2.5 volts being allowed. What is the size of the wire?

SOLUTION.—The number of lamps is 600 = N ; the distance is 160 feet = F , and the drop is 2.5 volts = E . Then, by the preceding formula, the area of the wire in circular mils.

$$A = \frac{10.8 \times 600 \times 160}{2.5} = 414,720 \text{ circ. mils. Ans.}$$

1290. It is, of course, necessary to check this result by finding the safe carrying capacity of the wire. The current taken by 600 lamps of 16 c.p. and 110 volts will be $600 \times .5 = 300$ amperes, and comparison may be made with the subjoined table, which gives the carrying capacity of concealed cables, the difference between successive sizes being 100,000 circular mils. Any intermediate size will have proportional capacity :

TABLE 46.

CURRENT CAPACITY OF CABLES.

Area in Circular Mils.	Current in Amperes.	Area in Circular Mils.	Current in Amperes.
200,000	200	1,100,000	673
300,000	272	1,200,000	715
400,000	336	1,300,000	756
500,000	393	1,400,000	796
600,000	445	1,500,000	835
700,000	494	1,600,000	873
800,000	541	1,700,000	910
900,000	586	1,800,000	946
1,000,000	630	1,900,000	981
		2,000,000	1,015

1291. In some cases the loss in E. M. F. in a circuit is given as a certain percentage. It is obvious, on consider-

ation, that this is not to be taken as referring to the voltage at the lamps, for the drop in potential is between the point of supply and the lamps, and the initial voltage is, therefore, higher than at the lamp terminals. In order, then, to ascertain the actual drop in the feeders, or conducting wires, the initial E. M. F. must be determined, and the lamp E. M. F. subtracted therefrom.

Rule.—*To find the drop in potential in a wiring system when the percentage of loss is given and the E. M. F. at the lamp terminals is known, multiply the lamp E. M. F. by 100 and divide by 100 minus the percentage of loss. The quotient will give the initial E. M. F., from which is subtracted the E. M. F. at the lamp terminals, the remainder being the actual drop in volts.*

This may also be expressed in algebraic form:

$$V_1 = \frac{100 V}{100 - p}; \quad (1.)$$

$$E = V_1 - V, \quad (2.)$$

where V_1 is the initial voltage, V the voltage at the lamp terminals, E the drop in volts, and p the percentage of loss.

EXAMPLE.—What will be the actual drop in voltage on a 110-volt circuit when a three per cent. loss is allowed for?

SOLUTION.—The E. M. F. at the lamp terminals is 110 volts = V , and the per cent. loss is $3 = p$. Then, by formula 1, the initial voltage $V_1 = \frac{100 \times 110}{100 - 3} = 113.4$, and by formula 2, the drop in voltage $E = 113.4 - 110 = 3.4$ volts. Ans.

1292. Size of Conductors for Three-Wire System.—Since in the three-wire system the lamps are arranged across the main wires in groups of two, the current supplied is only one-half of that required for a multiple-arc system, and the electromotive force is double. It therefore follows that the wire for these outer conductors need be only one-quarter the size necessary in the two-wire system; when the third, or neutral, wire is of the same size as the outer wires,

the total amount of copper required is only $\frac{1}{4} + \frac{1}{8} = \frac{3}{8}$ of that necessary with the two-wire system, provided, however, that the same percentage drop of potential is used in the two cases. When the same drop is used, the size of wire in the three-wire system will be one-half that required for the two-wire system; for, although the resistance of the conductor for the three-wire system would thereby be doubled, the current is of only one-half the value, so that in the one case $E = C R$, and in the other case $E = \frac{1}{2} C \times 2 R$, which values are identical.

The formulas to use for calculating the size of wire for a three-wire system are the following:

$$R_f = \frac{2 E}{N F}, \quad (1.)$$

or, for wires of extra large capacity,

$$A = \frac{5.4 N F}{E}. \quad (2.)$$

The current in the outside conductors of a 110-220 volt three-wire system is found by dividing the total number of 16 c. p. lamps by 4. The outside wires must have a carrying capacity sufficient for this current. In using formulas 1 and 2, it must be understood that E is the total drop in the circuit. For example, if the pressure at the dynamo were 112 and that at the lamps 110, the drop on each side of the system would be 2 volts and the value of E would be 4. N is the total number of lamps operated and not the number on one side only.

EXAMPLE.—Three hundred 16 c. p. lamps are to be supplied by means of the three-wire system. The drop to the lamps, i. e., on each side of the circuit, must not exceed 5 volts. What will be the size of wire required if the lamps are located 1,500 feet from the dynamo?

SOLUTION.—We have from formula 2,

$$A = \frac{5.4 N F}{E} = \frac{5.4 \times 300 \times 1,500}{10} \\ = 243,000 \text{ circular mils. Ans.}$$

A stranded cable would probably be used for this conductor.

1293. Arrangement of Circuits.—A group of different methods of wiring for the two-wire system is shown in Fig. 485. It will be noticed that the closet *A* is so placed that the lamp-feet of the various branch circuits are approximately equal, so that the drop will be uniform in each. From the foregoing directions it will be easy to

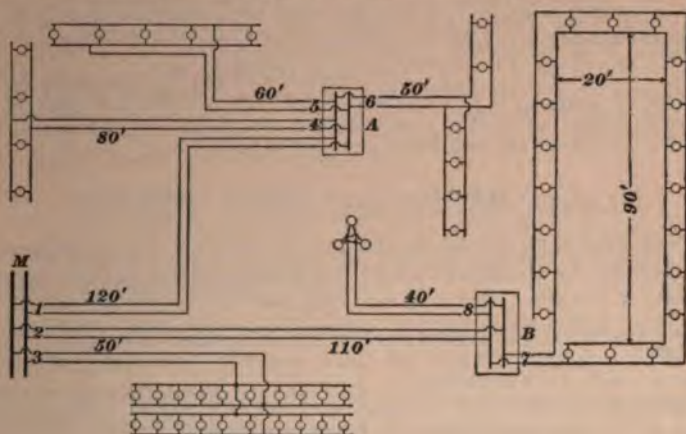


FIG. 485.

follow out the calculations for the wiring, as embodied in the example below:

EXAMPLE.—A floor of a building is to be fitted with incandescent lamps as indicated in Fig. 485. The mains enter at *M*; a drop of 2.5 volts is allowed between this point and the lamps; on each circuit the length in feet is marked, this being the single distance. The lamps are 110 volt, 16 c.p. Determine the size of feeders and branches.

SOLUTION.—Feeder No. 1 carries current for the lamps on circuits 4, 5, 6, having a total of 15 lamps. The distance from the main to the closet *A* is 120 feet, and the lamp-feet = $15 \times 120 = 1,800 = NF$. The total drop allowed is 2.5 volts, of which we will use here, say 1.5 volts = *E*. Then, by formula 2, Art. 1280, the resistance per foot of the wire

$$R_f = \frac{1.5}{1,800} = .000833 \text{ ohm, or per 1,000 feet} = .833 \text{ ohm.}$$

The nearest size of wire is No. 9. The current passing through the conductor is $15 \times .5 = 7.5$ amperes, which is much below the underwriters' limit, and is safe.

P. H.—32

Subfeeder No. 4 carries current for 4 lamps a distance of 80 feet, and the lamp-feet = $320 = NF$. The drop in voltage will be the difference between the total drop allowed and that taken for the feeder in series with this subfeeder; then $2.5 - 1.5 = 1$ volt = E . The resistance per foot of the wire will be

$$R_f = \frac{1}{320} = .003125 \text{ ohm, or per 1,000 feet} = 3.125 \text{ ohms.}$$

This is smaller than No. 14, but we must use this wire, as it is the smallest allowed (Art. 1287). The current is only $4 \times .5 = 2$ amperes, and No. 14 will carry 10 amperes, and is, therefore, safe.

Subfeeder No. 5 carries current for 5 lamps a distance of 60 feet, and the lamp-feet $NF = 300$. The drop is the same as for circuit 4, and $E = 1$. Then, the resistance per foot of the wire,

$$R_f = \frac{1}{300} = .00333 \text{ ohm, or per 1,000 feet} = 3.33 \text{ ohms.}$$

The nearest wire is again No. 14, and the current is $5 \times .5 = 2.5$ amperes.

Subfeeder No. 6 supplies current to 6 lamps, and the distance being 50 feet, $NF = 300$. The drop is 1 volt, and the resistance per foot

$R_f = \frac{1}{300} = .00333$, the same wire, No. 14, being used here also. The current is $6 \times .5 = 3$ amperes.

Feeder No. 2 is 110 feet in length, and supplies current to 23 lamps. Then $NF = 23 \times 110 = 2,530$. If we allow a drop of 1.5 volts here, we shall have only one volt to allow in circuit 7. But circuit 7 contains actually double the length of wire, and it would be a better plan, therefore, to allow 1.5 volts here, and 1 volt in circuit 2. Then, the wire for circuit 2 has a resistance per foot

$$R_f = \frac{1}{2,530} = .000395 \text{ ohm, or per 1,000 feet} = .395 \text{ ohm,}$$

which is between Nos. 5 and 6, either of which will carry the current safely. We regulate our choice by the result of the subsequent calculation on circuit 7.

Subfeeder No. 7 carries current for 20 lamps, arranged in a loop. We have seen (Art. 1288) that the distance used in calculation is $90 + 20 = 110$ feet = F , then the lamp-feet $NF = 20 \times 110 = 2,200$, and the drop in volts is $1.5 = E$. Then the resistance per foot of the conductor,

$$R_f = \frac{1.5}{2,200} = .000682 \text{ ohm, or per 1,000 feet the resistance is .682 ohm,}$$

corresponding to a size between Nos. 8 and 9, but nearer No. 8. If we use the larger wire here, No. 8, we should use the smaller of the two in the case of the feeder to this closet, No. 2, which we find should be between Nos. 5 and 6. Therefore, we select No. 6 wire for circuit No. 2. For circuit 7, No. 8 wire is safe, the current being 10 amperes.

Subfeeder No. 8 runs to an electrolier with only three lights, the distance being 40 feet. The drop in this line should be $2.5 - 1 = 1.5$ volts. The resistance per foot of the wire will then be

$$R_f = \frac{1.5}{120} = .0125 \text{ ohm, or per 1,000 feet} = 12.5 \text{ ohms.}$$

This wire will be much too small to use, and we must take No. 14, although these three lamps will run brighter than the others. We may find the drop from formula, Art. 1286; $E = .00263 \times 120 = .3156$ volt, instead of 1.5, so that the lamps will have 1.18 volts excess of pressure. This, however, will not injure them.

Feeder No. 3 carries the current for 20 lamps a distance of 50 feet. The drop is 2.5 volts, and the lamp-feet = 1,000 = $N F$. The resistance per foot of the required conductor

$$R_f = \frac{2.5}{1,000} = .0025 \text{ ohm, or per 1,000 feet} = 2.5 \text{ ohms.}$$

No. 14 wire is sufficiently near the size to use, and will carry the current, 10 amperes, safely. Ans.

1294. Wiring in Large Buildings.—For a large building, separate circuits may be run to the top floor up two or more vertical corners. One of these circuits is shown in Fig. 486. The terminal board of the dynamo is shown at *s*, corresponding to the junction-box in a public supply system, and *a b c* represents one set of feeders, which is connected to central points on the subfeeders *e f*, these again being connected to the mains *m n* at such points as will ensure the best distribution of current. Tap circuits are provided for the lamps on the several floors, cut-outs being placed at all branches.

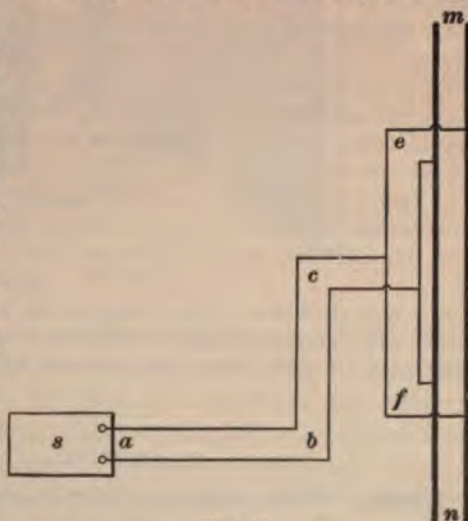


FIG. 486.

1295. In calculating the size of the feeders, the proportionate number of lamps for each one is considered as determining the current it carries; for instance, if there are two feeders at opposite corners, each may be regarded as supplying current to one-half the lamps on each floor, although the lamps may be connected to a common set of mains.

For the three-wire system, three wires for each set of feeders, or mains, are carried throughout, except in the small tap circuits.

EXAMPLES FOR PRACTICE.

1. A group of thirty-three 110-volt 16 c.p. lamps is located 325 feet from the closet. What size feeder will be required, a drop of $2\frac{1}{2}$ volts being allowed? Ans. No. 3 B. & S.

2. A 6-light electrolier is set up at a distance of 35 feet from the mains. There are three lamps of 16 c.p., two of 32 c.p., and one of 50 c.p., the circuit being 55 volts. With a drop of $1\frac{1}{2}$ volts, what size wire should be used? Ans. No. 13 B. & S.

3. What would be the drop in the circuit mentioned above, if No. 12 wire were substituted for No. 13? Ans. 1.16 ohms.

4. A hall 30 ft. wide by 95 feet long is provided with seventy-five 16 c.p. 110-volt lamps, the wiring being arranged in the form of a loop, and the lamps mounted on the walls. Allowing a drop of 2 volts, what size wire should be used? Ans. No. 3 B. & S.

5. What size conductor will be required to carry the current for four hundred and fifty-two 110-volt 16 c.p. lamps at a distance of 374 feet, the allowable drop being 2 per cent.? Ans. 815,052 circ. mils area.

6. On a three-wire system there are to be installed sixty-two 110-volt 16 c.p. lamps at a distance of 235 feet from the closet, a drop of 3 volts being allowed. What size conductor will be required? Ans. No. 6 B. & S.

TESTING.

1296. When wiring is being installed, it should be frequently tested, to ensure the discovery and correction of faults in the insulation, while they may be easily repaired. The method employed is to free one end of the conductor from contact with other objects, and connect the other end

to one terminal of a testing instrument, the second terminal being "earthed," or "grounded" through a gas or water pipe. The resistance of such a circuit will necessarily be very high, preventing the passage of any appreciable current; but if there is a fault at any point, a current of larger volume will flow through. A convenient form of testing instrument is the **magneto** shown in Fig. 487. The terminals, or binding posts, to which connections are made, as already described, are on the upper side at *t*, *t'*.

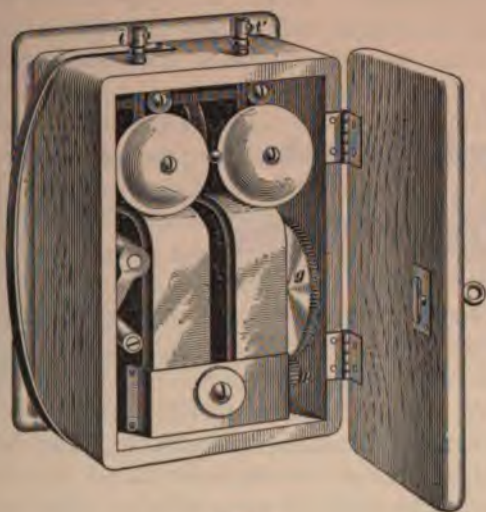


FIG. 487.

A crank-handle on the outside of the case turns the pinion *p* through the gear-wheel *g*, thereby revolving the armature of a small dynamo. If there is a fault on the line and connections are made as directed, the bell will ring on turning the crank. Care should be taken to ascertain that the gas or water pipes used for the connections are actually in communication with the street mains. The wiring will be passed by the insurance inspectors if a magneto that will ring through a resistance of 20,000 ohms shows no grounding of the circuit.

BELL WORK.

BELL CONSTRUCTION AND OPERATION.

APPARATUS FOR BELL CIRCUITS.

1297. In nearly all electric appliances, particularly in those we are about to describe, the **electro-magnet** is an all-important feature. It was early discovered that when a current of electricity circulated through a coil of wire, magnetic poles were developed at each end of the coil, hav-

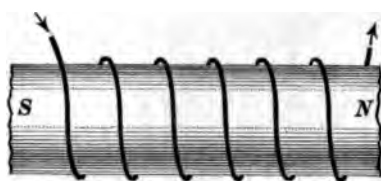


FIG. 488.

ing the same properties of attraction and repulsion as a permanent steel magnet. If a piece of iron be inserted in the coil, as in Fig. 488, the magnetic effects are much intensified; one end

N of the iron core becomes a north pole, the other *S* a south pole, corresponding to the polarity of the coil before the introduction of the iron core. To prevent diversions of the current, the wire should be wrapped around with cotton or other insulating substance. The intensity of magnetization depends on the amount of current flowing, also upon the number of turns of wire; the current then being measured in amperes, the magnetization is dependent upon the number of ampere-turns. Since the currents used in bell and signal work are very small, it is necessary to wind a large number of turns around the magnet cores, thereby producing the same effect as would be obtained by a few turns of wire carrying a heavy current.

1298. The most usual form of electro-magnet for bells is that shown in Fig. 489, and is made in three parts, namely, two iron cores, such as *AI*, wound with the magnetizing coils, and a straight bar of iron *b* joining the two cores. The current passes through the coils in series, and

should circulate around one core in the opposite direction to that taken around the other, producing a north pole at the free end of one core, and a south pole at the free end of the other, as this condition will give the greatest attractive power for the bar of iron, called the **armature**, which is generally used in connection with this form of electro-magnet.

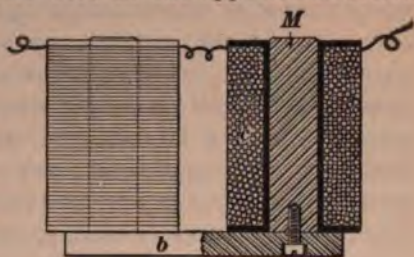


FIG. 489.

1299. The principle involved in the action of the **electric bell** is an alternate attraction and release of a

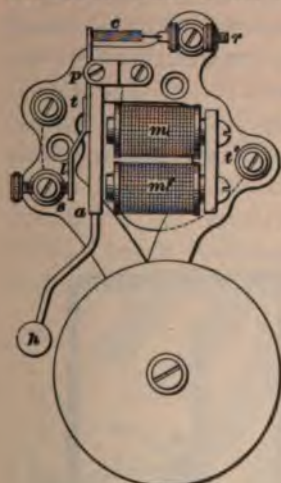


FIG. 490.

soft iron armature placed in front of an electro-magnet and carrying a hammer, the motion being due to intermittent currents through the wire of the electro-magnet. In Fig. 490 is shown a type of skeleton bell, in which all the parts are visible. The battery wires are connected at the terminals t , t' , and the course of the current is as follows: From the terminal t to the adjustment screw s , which is tipped with platinum in order to prevent oxidation of the contact surface, through the spring l and the end of the armature a to the coils of the magnets m , m' , and out at the terminal t' . When no current is passing, the armature is held away from the poles of the electro-magnets, as in the position shown, but as soon as a battery is connected up and a current sent through the coils, the magnets become energized and attract the armature a , which swings about the pivot p , causing the hammer h to strike the bell. This movement breaks the circuit at s and t , and the iron

cores being thereby demagnetized, the spring *c* draws the armature away, when the spring *l* again touches the screw *s*, completing the circuit. As long, then, as the battery current is free to flow, this vibration of the armature and hammer will continue. The tension of the release spring *c* may be changed to suit the strength of the battery by means of the regulating screw *r*, which is provided with nuts for this purpose on each side of the supporting pillar. The bell mechanism is usually enclosed, to prevent entrance of dust or insects, which may interfere with the working of the bell by lodging on the contact points, thereby preventing the current from passing through the magnets.

1300. The bell just described is of the common vibrating class. When a bell is required to give a single stroke each time the circuit is closed, that is, for each pulsation of current, a slight difference in the connection of the ordinary bell will accomplish this. A wire is connected between the end of the magnet coil *m* and the terminal *t*, so that the circuit is simply from one terminal to the other through the coil. Hence, when a current passes through, the armature is attracted and held, a single stroke being given to the

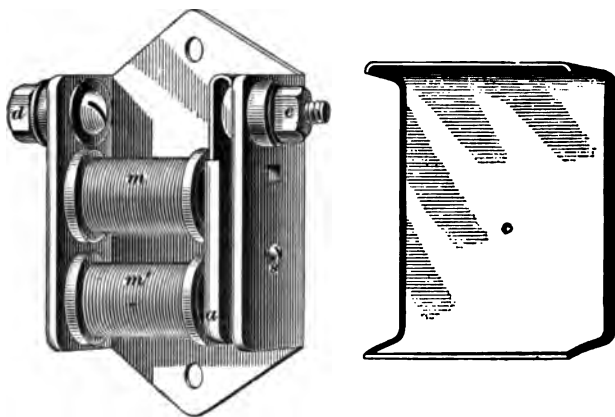


FIG. 491.

bell; on interrupting the current, the armature is drawn back to its normal position by the spring *c*.

1301. The **buzzer**, Fig. 491, is used in places where an electric bell would be undesirable, as in small, quiet rooms or on desks, and is constructed on the same principle as the bell, except that the armature does not carry a hammer. In the illustration, the cover *c* is removed, showing the magnet coils *m*, *m'* and the armature *a*. An adjusting screw *s* is provided to regulate the stroke of the armature and the consequent intensity of sound. The wires from the push-button and battery are secured at *d* and *e*, and, on closing the circuit, the rapid vibration of the armature causes a humming or buzzing sound, whence the name.

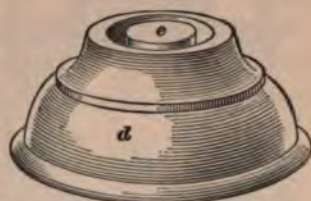


FIG. 492.

1302. The circuit-closing devices used for electric bells are quite different from those used on lighting circuits, as the current and E. M. F. in the former case are very small, and there is no burning of the contacts. The ordinary switch for closing the circuit of an electric bell is called a **push-button**, and is illustrated in Fig. 492. The ends of the line wire are brought up through a hole in the wooden base *a*, and held under the screws on the brass contact springs *b*, *c*. The cap *d*, in the lower view, when screwed in place, holds the ivory button *e* which, on being pressed down, forces the two springs together and completes the circuit, causing the bell to ring.

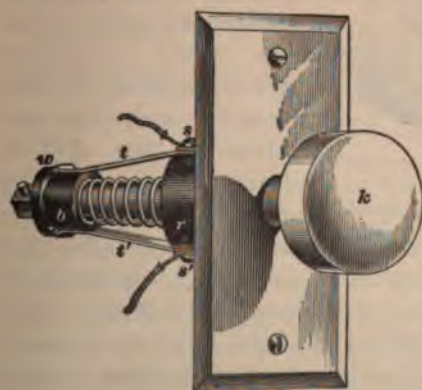


FIG. 493.

1303. An electric-bell switch may easily be

arranged in connection with the ordinary bell-pull of a front door, in the manner shown in Fig. 493. The wires from the bell and battery are made fast by the screws *s*, *s'* to the tongues *t*, *t'*, which are insulated from each other by the block *r* to which they are secured. The free ends press upon a rubber bushing *b*, and a brass washer *w* is drawn between the brass tongues, thereby closing the electric circuit when the knob *k* is pulled.

1304. The battery used for electric bells is illustrated in Fig. 494. This is the Leclanche cell, and consists of a



FIG. 494.

porous cup *P*, containing the carbon electrode *C*, to which a binding post *B* is attached; also a zinc rod *Z*, both being enclosed in a glass jar with a contracted top. The zinc rod is provided with a binding screw *B*₁, which serves as the negative terminal of the cell, *B* being the positive terminal. Before the battery will furnish current, the jar must be filled to the point shown in the cut with a saturated solution of sal-ammoniac, and, in connecting up, the zinc of

one is joined by a short piece of wire to the carbon of the next. This gives a series grouping, which is usually required in bell work. When, after considerable use, the current from the cells becomes feeble, it will be necessary to replace the liquid, but it frequently happens that the power may be restored by the addition of a little water to make up for evaporation. The zinc will, in course of time, be consumed, and must be replaced, and the sal-ammoniac may

also be renewed at the same time, although it should last longer than a single zinc rod of the usual size ($\frac{3}{8}$ in. diameter). After five or six rods have been used, the material inside the porous cup will no longer act effectively, and this means, practically, a new carbon and cup, since they may be procured very cheaply. In the case of renewal of a large number of cups, they may be returned to the manufacturer, and recharged by him.

1305. It is sometimes desirable to use current from a dynamo or from lighting mains to operate the bells. It will, of course, not be allowable to connect the bells directly across the line, because they would immediately be burnt out, and it is necessary to interpose sufficient resistance to cut down the current to the required amount. The resistance of a bell is usually about 20 ohms, and since it may be rung from one cell of battery, or two cells if there is a long line wire, the E. M. F. across the bell may be taken as 2 volts. The usual working current is then $\frac{2}{20} = .1$ ampere.

If we denote by x the resistance to be added, the total resistance $= x + 20$, which, by Ohm's law, equals $\frac{E}{C} = \frac{110}{.1} = 1,100$ ohms, and $x = 1,100 - 20 = 1,080$ ohms. The resistance of a 16 c.p. 110-volt lamp is, approximately, 220 ohms, and five lamps in series will be $5 \times 220 = 1,100$ ohms. The current will then be $\frac{110}{1,100 + 20} = .098$ ampere, which is near

enough to the required amount. The connections are shown in Fig. 495, where a , b are the 110-volt lighting mains, l the five lamps in series, and c , d the wires to the bells. If this current is found to be insufficient, one of the lamps may be cut out, when the total resistance will be

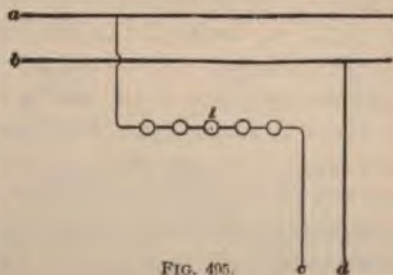


FIG. 495.

$(4 \times 220) + 20 + y$, the line resistance being denoted by y . If this is 2 ohms, the total resistance will be 902 ohms, and the current $= \frac{110}{902} = .122$ ampere, corresponding to an E. M.

F. across the bell of $\frac{20}{902} \times 110 = 2.44$ volts. An intermediate reduction of current may be obtained by substituting a 32 c.p. lamp for one of those of 16 c.p.

1306. For special alarm purposes, it is sometimes desirable that the bell should continue to ring after the push is released. This is accomplished by the use of an **automatic drop**, which closes an extra, or shunt, circuit as soon as a current passes along the main circuit. Fig. 496 shows two views of an automatic drop, *A* being a

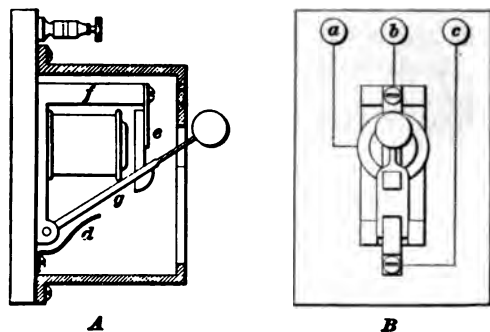


FIG. 496.

side elevation, and *B* a front view with cover removed. There are three terminals on the baseboard; those marked *a* and *b* are connected to the ends of the magnet coil, the end at *b* being also connected to the frame *f*; terminal *c* makes connection to the spring contact *d*. The bell circuit is closed first through *a b* by means of the push-button; the armature *e* is at once attracted, thereby releasing the gravity spring *g*, which makes contact with the spring *d*, establishing a circuit between *b* and *c*, which cuts out the push-button.

ARRANGEMENT OF BELL CIRCUITS.

1307. A simple bell circuit is shown in Fig. 497. A battery of two Leclanche cells *c, c* connected in series furnishes current to the bell *b*, located at any part of the house, and the push-button *p* is placed at any convenient point.

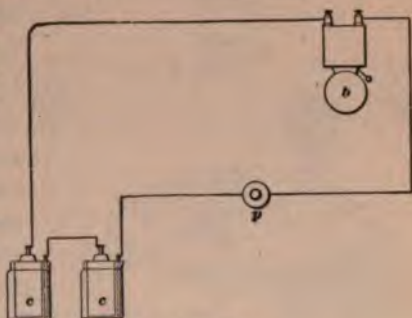


FIG. 497.

1308. It is frequently necessary to ring two or more bells from one push-button, and there are two methods of accomplishing this. One is to connect the bells in multiple-arc across the leads, as in Fig. 498, so that each one is independent of the others,

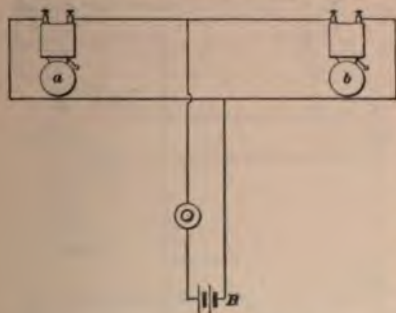


FIG. 498.

the bells *a, b* being on separate circuits. The battery *B* is represented in this diagram in the manner generally adopted, the fine line indicating the carbon of the cell and the heavy line the zinc. The other method, making use of a series arrangement, is shown in Fig. 499. This

is often preferred to the first method, because there is usually a saving of wire in its employment, but it is necessary to change all but one of the bells to single stroke, as already explained. The reason for this is that unless the bells were exactly similar in their adjustment, the period of vibration, or rate of swing, of the armatures would be different, and the interference would prevent

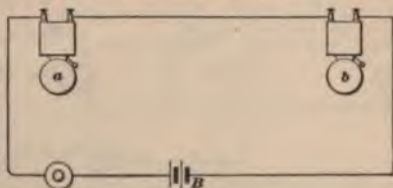


FIG. 499.

satisfactory ringing of the bells. If, however, one bell is free to vibrate, and the rest are all changed to single stroke, very little adjustment to each one will be required to produce a strong, clear ring.

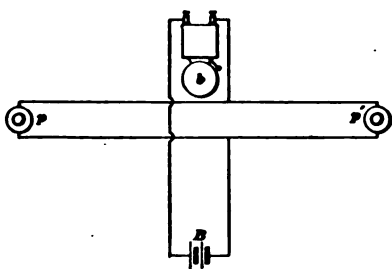


FIG. 500.

button, and a current would not flow unless both buttons were pressed at once. The second button must then be in parallel to the first, as in Fig. 500, so that whichever button *p* or *p'* is pressed, the circuit through the bell *b* and battery *B* is completed.

1310. Figs. 501 and 502 show two arrangements of wiring for ringing two bells simultaneously from three different points. The bells *a*, *b* are connected in multiple-arc (or parallel) in Fig. 501, but they may be put in series if desired, as in Fig. 502,

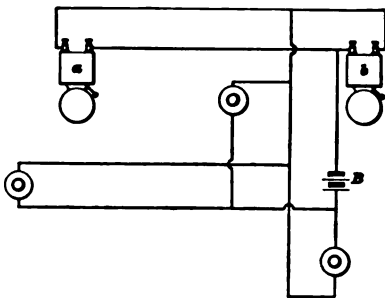


FIG. 501.

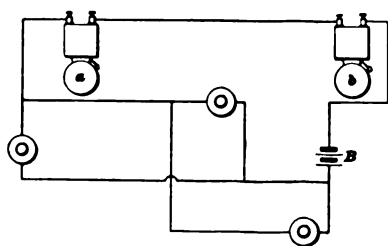


FIG. 502.

provided one of them is changed to single stroke. In the case of an actual installation, it might be necessary to run the wires in some other manner than as here laid out, dependent upon the construction of the building; but, from the directions already given, it should be an easy matter to devise the best arrangement. The choice between series

and parallel connection of the bells will depend upon which is more economical in copper for the line wires. The wire to use will be No. 14, 16, or 18 office wire, according to the number of bells on the circuit.

1311. When two bells are arranged to ring from one push-button, it is sometimes desirable to cut one of them out during some part of the day. For this purpose a small switch, Fig. 503, is used, by means of which the bell may be short-circuited. The wires are run to the back of the switch, one connection being to the lever arm at *a*, the other to the contact piece *b*.



FIG. 503.

1312. The connections for the automatic drop are shown in Fig. 504. The circuit obtained on pressing the push-button *p* is from the positive pole of the battery *B* through the push

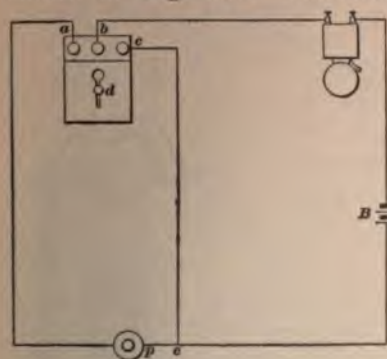


FIG. 504.

to the terminal *a* of the drop, through the magnet coils to terminal *b*, then to the negative pole of the battery by way of the bell. Immediately the drop *d* falls, the magnet coils are cut out, the current being diverted at *e*

and passing by way of the new contact from terminal *c* to *b*, thence through the bell, as before, to the battery.

ANNUNCIATORS.

1313. When a number of push-buttons is used in a call-bell system, as in the different rooms of a house or hotel, it becomes necessary to provide some means of

determining which of these buttons has been pressed when the bell rings, in order that the call may be answered. The instrument employed is called an **annunciator**,

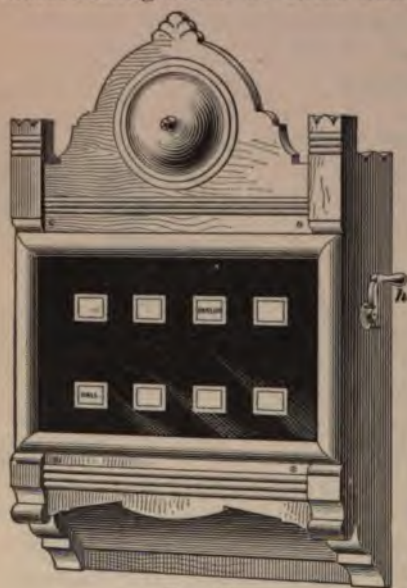


FIG. 505.



FIG. 506.

and the ordinary house style is shown in Fig. 505. On the face are rows of small windows, before one of which an indicator appears when the bell rings, showing from which room the signal has been sent. A handle *h* at the side is intended to be used to restore the indicators to their normal position when the call is answered. A view of the indicator itself is given in Fig. 506. A hinged arm *a* carries a card, bearing the name or number of the room to which the drop is connected, and is held up in the position shown, by a counterbalanced trip *t* in front of an electro-magnet *m*. As soon as a current passes through the electro-magnet the trip is attracted and the indicator falls, being then visible from the outside, through one of the openings in the front.

1314. The **needle annunciator**, Fig. 507, is a style much used in hotels and for elevators. The current, on passing through



FIG. 507.

the electro-magnet of an indicator, attracts a pivoted iron armature carrying a pointer p on the outside dial, causing it to set in an oblique position, in which it is held by a catch until released by pressing the knob k below the case.

WIRING FOR SIMPLE ANNUNCIATOR.

1315. A wiring diagram for a simple annunciator system is shown in Fig. 508.

The pushes 1, 2, 3, etc., are located at convenient points in the various rooms; one terminal being connected to the battery wire b , and the other to the leading wire l communicating with the annunciator drop corresponding to that room. A battery of three or four Leclanche cells is placed at B , in any convenient location, but should not be set in a dark or inaccessible spot, or exposed to frost.

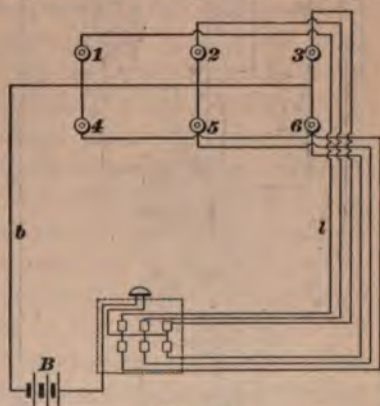


FIG. 508.

WIRING FOR RETURN-CALL ANNUNCIATOR.

1316. In Fig. 509 is illustrated a return-call system requiring one battery wire b , one return wire r , and for each room one leading wire l , l' , etc. The annunciator board is divided into two parts, the upper part having the numbered drops, and the lower the return-call pushes. Each room is provided with a double-contact push, such as that in Fig. 510. The tongue t makes connection normally with the upper contact c , but when pressure is put on the knob k , the tongue is forced against the lower contact c' . The return-call pushes on the lower board of the annunciator are of the same description, but all these pushes are shown diagrammatically in Fig. 509, for convenience in tracing out the circuits. The closing of the circuit by pressing the push-button in any room, as, for example

No. 4, rings the office bell and releases the corresponding

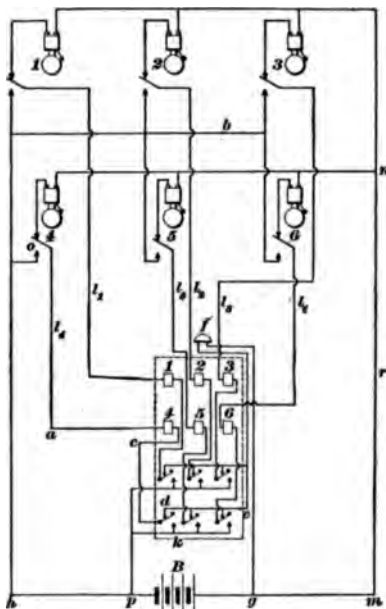


FIG. 509.

drop. The path of the current is then from the push *4* to *a c d e f g B h b*, and back to the lower contact of the push-button. On the return signal being made from the office, the annunciator-bell circuit is broken at *d*, and, the push-button in the room being released, a new circuit is formed through *k*, as follows: From the bat-

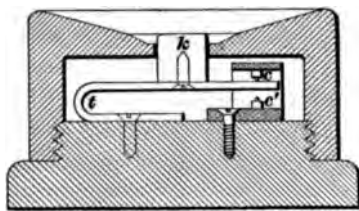


FIG. 510.

tery *B* to *g m r n o a c k p* to the battery, the room bell being in this circuit.

1317. In installing annunciator systems, it is usual to run the battery wire, which is No. 14 or 16 annunciator wire, through the building at some central portion. If there are many rooms, it will be advisable to splice on a length of No. 18 wire to extend from the push in each room to the battery wire. The connection from the other side of the push-button to the annunciator, that is, the leading wire, should be No. 18. For the return-call system, a battery of four or five Leclanche cells is required.

1318. All wires used in annunciator service should have distinguishing colors to prevent confusion. The battery wire may be blue, the return wire red, and the leading wires white. This arrangement will greatly simplify the connections, and reduce the liability of mistake.

WIRING FOR ELEVATOR ANNUNCIATOR.

1319. The wiring for an elevator annunciator is not materially different from that used in the simple annunciator described in Art. **1315**.

A single No. 14 wire *b*, Fig. 511, is connected to one pole of the battery *B* and carried all the way up the elevator shaft, where connection is made to the pushes at each floor, as shown at 1, 2, 3, 4. The wires leading to the annunciator, in the elevator *e*, are laid side by side, and are made up into a single cable *c* for convenience, each wire being independently insulated; one end of the cable is then made fast at a point *a* midway up the elevator shaft, and connections are made from the remaining terminals of the push-buttons to the wires in the cable leading to the corresponding annunciator drops. The electrical circuit is completed by a return wire *r* to the battery.

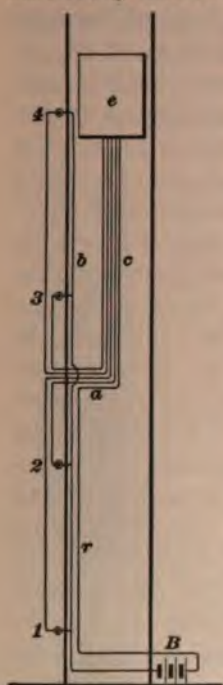


FIG. 511.

SPECIAL ELECTRIC FITTINGS.

THE ELECTRIC DOOR-OPENER.

1320. In apartment houses the mechanical door-opener is frequently replaced to advantage by one operated electrically. A view of one of these is given in Fig. 512, which shows the position of the different parts when the door is open. The latch *a* slides horizontally, being guided at the back by the rod *r*, and is moved by the lever *l*, which is pivoted at its center *o*. A cam *c* is connected to the pin *p*, which has, at its lower end, a crank *b*, held in the position shown, by means of a powerful spiral spring *s*; when the door is closed, the cam is forced around against this spring, thereby turning the crank *b*, so that the coil spring *d* is extended. If the latch lever *l* were free to move, it would at once fly back on account of this tension, carrying the latch with it; but the lower end of the lever

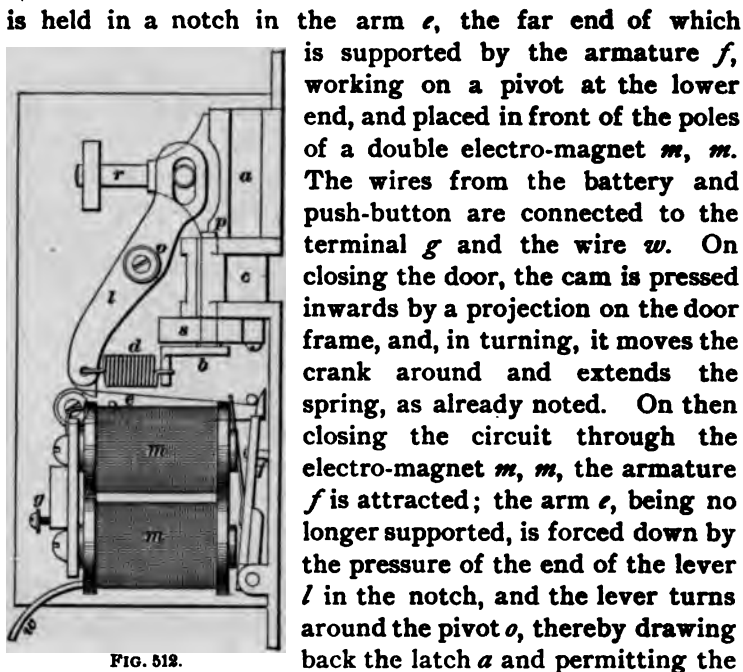


FIG. 512.

is held in a notch in the arm *e*, the far end of which is supported by the armature *f*, working on a pivot at the lower end, and placed in front of the poles of a double electro-magnet *m, m*. The wires from the battery and push-button are connected to the terminal *g* and the wire *w*. On closing the door, the cam is pressed inwards by a projection on the door frame, and, in turning, it moves the crank around and extends the spring, as already noted. On then closing the circuit through the electro-magnet *m, m*, the armature *f* is attracted; the arm *e*, being no longer supported, is forced down by the pressure of the end of the lever *l* in the notch, and the lever turns around the pivot *o*, thereby drawing back the latch *a* and permitting the door to be opened. As soon as this is done (the pressure being removed from the cam), the spiral spring revolves the crank, and, compressing the spring *d*, pushes the latch lever *l* back to its original position; the arm *e* also returns to a horizontal position, by spring pressure, as soon as the lever enters the notch. The armature *f* flies back from the magnet face as soon as the current is cut off, so that the apparatus is ready for operation again after the door has been opened and closed. Since, in closing the door, the latch will not move back, an extra spring latch is provided on the door frame; this is also convenient when opening the door by hand from the inside.

BURGLAR ALARMS.

1321. Automatic switches may be placed on windows and doors, in connection with alarm bells, to indicate when entrance into a building is being forced. There are two methods of installing these alarms: the open-circuit and

the closed-circuit systems. The **open-circuit system** is usually employed, in which the connections are entirely similar to those of an ordinary electric-bell circuit, the automatic circuit-closing device being substituted for the push-button. A window-spring employed in this system is shown in Fig. 513. This is let into the window frame, the cam c alone projecting; when the window is raised, the cam is pressed in, revolving about the pin p , and makes contact with the spring s , which is insulated from the plate by a washer at the lower end, and is nominally prevented from touching the cam by an insulating wheel w . The wires



FIG. 513.

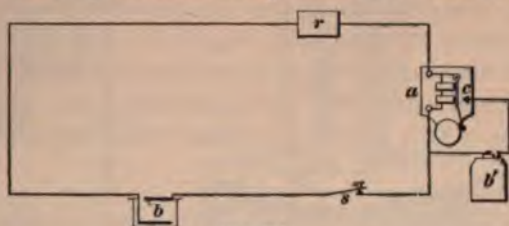


FIG. 514.

from the bell and battery are connected to the plate and spring, respectively.

1322. In the **closed-circuit system**, automatic switches of various styles are employed, but the contacts are held together when the alarm is set, and a movement of the window or door breaks this contact. Two batteries are required for this system, one being a closed-circuit gravity battery, indicated at b in Fig. 514, connected in series with a resistance r of about 200 ohms, the magnet coils of the bell a , and the alarm switch s . The armature of the bell is thus held away from the back contact c . The open-circuit Leclanche battery b' is connected to this contact and to the far terminal of the magnet coils; the circuit is, therefore, nominally open, but, as soon as the main circuit is opened, by moving the alarm switch, the spring on the armature of the bell presses it against the back contact, thereby closing the local circuit through the bell.

RUNNING THE WIRES.

1323. The directions given in Arts. 1267 to 1273 for running wires apply to bell work in some degree, but in this work, the wires may be laid side by side, provided they are properly insulated. All wires should be concealed, running them under molding or behind the baseboards of rooms or hallways when convenient. When it is necessary to

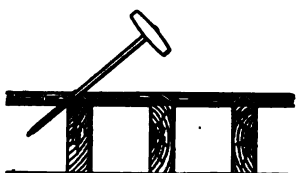


FIG. 515.

cross a room, it is the best practice to run parallel with the joists under the floor; but when the wire must run across the joists, **fishing** must be resorted to. The method employed is illustrated in Fig. 515. The joists *j* are located, and diagonal holes are bored through the floor on each side, through which the wires are drawn by means of a fishing wire, which is a steel ribbon made specially for this purpose.

1324. When a push-button is to be placed on a double partition, a $\frac{3}{8}$ -inch hole is drilled at that point, and a weighted line is dropped through in the intervening space. The line is then fished out at the floor level, and the wire attached. By the exercise of patience and ingenuity, it is possible to wire an old building in such a manner that there will be no trace visible of the wiring. All holes used in fishing should be filled with wooden plugs after the wires are in place.

ELECTRIC GAS-LIGHTING.

BURNERS FOR PARALLEL SYSTEM.

1325. In the application of electricity to gas-lighting, a spark is caused to pass between two conductors, placed near the burner, at the same time that the gas is turned on. In the **parallel system** of lighting, each burner is independent of all the others, having direct connection between the battery wire and ground. Three different styles of burner are used: the *pendant*, the *ratchet*, and the *automatic* burner.

1326. The **pendant burner** is shown in Fig. 516. A well-insulated wire is brought to the burner and secured under the head of the screw *s*, thereby making connection to the stationary contact piece *c*, which is fastened by a screw *l* to the frame *f*, and insulated from it by washers *w*. On pulling the pendant *r* downwards, the spring *a* is drawn across *c*, and, on passing off at the upper side, the break causes a spark which, when the gas has been turned on, will ignite it.

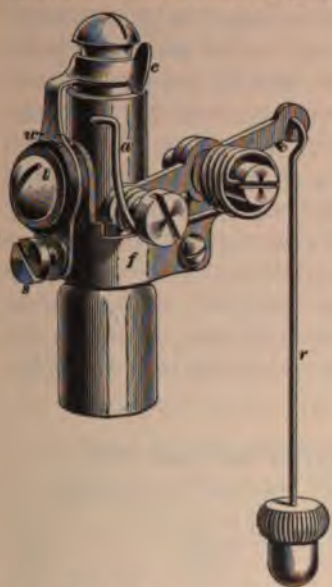


FIG. 516.

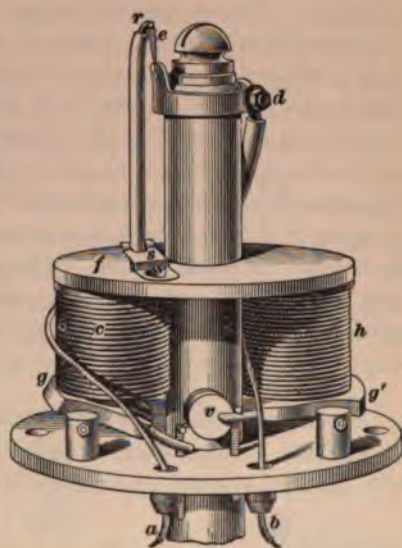


FIG. 517.

1327. The **ratchet burner** is very similar to the plain pendant, and is provided with a ratchet and pawl operated by a pendant, a downward pull turning on the gas at the same time that the spark is produced. A second pull extinguishes the gas.

1328. The **automatic burner** is shown in Fig. 517, with the cover removed. Two wires must be provided, running from a double push-button, one of them leading to the wire *a*, and the other to *b*. The circuit from *a* is through the left-hand magnet coil *c* to the insulated band *d*, which

has a projection e at one side. Upon this rests a metal rod r , bent at the upper end, and terminating in a contact piece; at the lower end the rod is grounded by connection with the frame f . Each magnet coil has an armature g or g' , with a projecting finger on the inner side. When current is sent through the magnet c , the armature g is raised and turns the gas valve v by striking one of the pins. At the same time the rod r is pushed up, thus breaking the circuit at a point where the gas is escaping, and producing a spark which will ignite it. To provide for certain action, the sparking should continue later than the instant of turning on the gas, and this is effected by the use of a spring to restore the circuit. The rod r is forced upwards against the spring s , but, when the circuit is opened at the spark gap, the spring presses the rod and armature down again, and, the circuit being thereby closed, a spark is again produced on opening. This continues as long as the push-button is pressed, the action being similar to that of an electric bell. The second coil h is grounded at the inner end, and, when a current is sent through, the armature g' is raised, turning the valve and cutting off the supply of gas.

ARRANGEMENT OF LIGHTING APPARATUS.

1329. The apparatus used in electric gas-lighting, on the parallel system, consists of a battery of about six cells, of

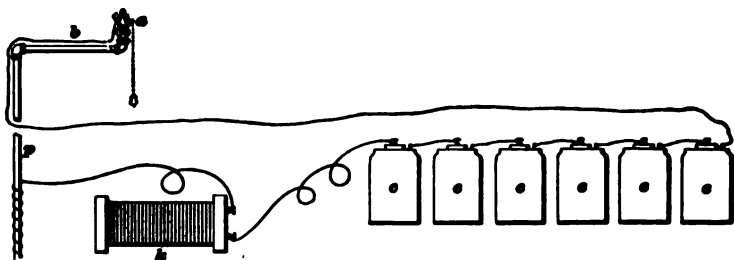


FIG. 518.

a type giving a strong current, such as the Fuller mercury bichromate battery, and of a spark coil connected in series with it. The spark coil has a single circuit of fine wire, and its action is to produce a spark by self-induction on opening

its circuit, when used in connection with the battery. The arrangement of the apparatus is shown in Fig. 518, where *k* is the spark coil, connected at one side to the gas pipe *p*, and at the other side to the first cell of the series *c*, *c*, etc. From the last cell, a well-insulated wire is carried up to the gas bracket *b*, and connected to the tip, as already described, the circuit to ground being completed through the sliding contact lever *a*. In applying the gas-lighting system to chandeliers, the wire is run in the space between the gas pipe and outer tube, and great care must be exercised in insulating at all points where sharp metal edges are passed, as the E. M. F. used is very high. Gas brackets usually have but a single pipe, and the wire should be run on the lower side, being tied on with thread and shellacked. When the shellac is dry, the thread may be removed, and the wire will adhere to the metal. A short helix should be made wherever there is a joint, to prevent the wire from breaking as a result of frequent turning of the bracket. The wire used for this part of the construction is No. 20 or 22, B. & S. gauge, well insulated, and colored to suit the bracket. For the house circuits, No. 14 or 16 wire should be used.

1330. A diagrammatic arrangement of gas-lighting apparatus is shown in Fig. 519, indicating the method of

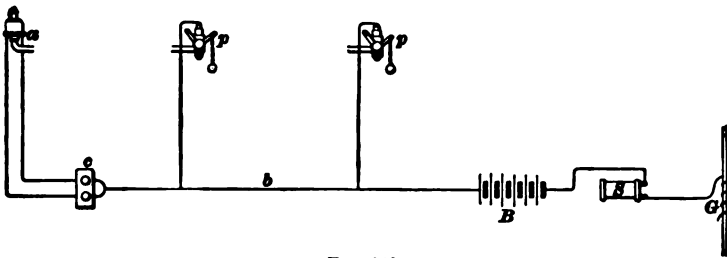


FIG. 519.

connection of the automatic and pendant burners. The spark coil *s* is grounded at *G*, and connected to the battery *B* at the other terminal. The battery wire *b* runs the full length of the circuit, branches being taken to the pendants *p*, *p*, and double wires to the automatic *a*, the battery

wire connecting with both buttons of the double push-button *c*.

1331. Since the battery is momentarily short-circuited every time a spark is obtained, it would soon run down if the contacts on the burner were to remain permanently touching. To give notice of this, a **relay** (Fig. 520) may be used in series with the battery, the current entering at *b* and passing out at *c*, after circulating around the coil. The magnetic circuit is completed by an armature *a*, which is

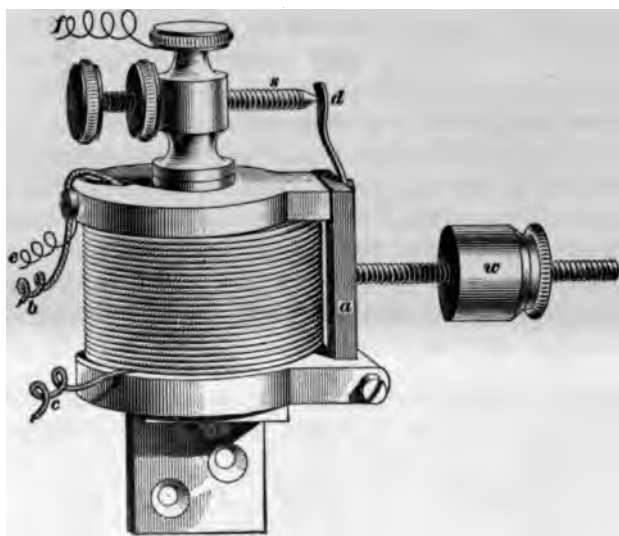


FIG. 520.

held back against a stop by the weight *w* when no current is passing. If a short-circuit occurs, the armature is attracted, and the spring *d* is pressed against the platinum-tipped screw *s*, completing a local circuit, by means of the wires *e*, *f*, through a vibrating bell and one-cell battery. The current used in lighting the gas at a burner is of such short duration that the bell is not rung. A modification of this arrangement is to provide an armature on the spark coil itself, which shall close a local alarm circuit when the battery is short-circuited.

APPARATUS FOR MULTIPLE-LIGHTING SYSTEM.

1332. The **multiple, or series, system** of gas-lighting is used in large halls where many lights are installed in groups. A fixed spark gap is used at each burner, both of the points being insulated from each other and from the gas pipe, except the last point of a series, which is grounded. The style of burner used is shown in Fig. 521, in which *a* and *b* are the points of the spark gap. To complete the connection between consecutive burners, a fine, bare copper wire, about No. 26 gauge, is stretched across, being secured through the small holes at the lower ends of the strips *a*, *b*. The body of the burner is made of some insulating substance, and a flange of mica *m* is added to give further protection. Since one circuit may consist of a large number of burners, it will be seen that the E. M. F. must be very high to force a current across so much air space, and, to ensure success, the wiring must be installed with the greatest precautions. The wire should nowhere be nearer than $1\frac{1}{4}$ inches to the gas pipe, but where it is necessary to approach closely, the wire should be enclosed in glass tubing.

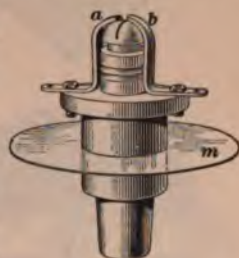


FIG. 521.

The apparatus required for this system of gas-lighting consists of an induction coil *i*, Fig. 522, operated by a bat-

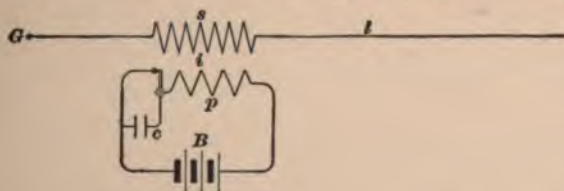


FIG. 522.

tery *B*, and used with a condenser *c* across the spark gap of the primary *p*. The condenser cuts down the spark at the circuit-breaker, for this spark would be very destructive in the case of a large coil. The fine wire secondary *s* is

grounded at *G*, and the other terminal is connected to the line wire *l* passing to the burners.



FIG. 523.

One form of this machine is shown in Fig. 523. One of the terminals *l* is to be connected to the switch handle *s*, and the other *g* to ground. The machine is revolved by means of the handle *h*, and the switch is moved from one contact to the next, lighting the gas on each circuit 1, 2, 3, 4 in rapid succession.

1333. Frictional machines are also used in the multiple-lighting system, and generate static electricity, such as is produced when a rubber comb is passed through the hair. One form of this machine is shown in Fig. 523. One of the terminals *l* is to be connected to the switch handle *s*, and the other *g* to ground. The machine is revolved by means of the handle *h*, and the switch is moved from

A SERIES
OF
QUESTIONS AND EXAMPLES

RELATING TO THE SUBJECTS
TREATED OF IN THIS VOLUME.

It will be noticed that the questions and examples contained in the following pages are divided into sections corresponding to the sections of the text of the preceding pages, and that each section has a headline which is the same as the headline of the section to which the questions refer. No attempt should be made to answer any questions or to work any examples until the corresponding part of the text has been carefully studied.

PLUMBING AND DRAINAGE.

(ARTS. 653-827.)

EXAMINATION QUESTIONS.

(387) What cements would you use for the following work, and how would you use them: (a) For jointing earthenware drain pipes? (b) for jointing marble slabs? (c) for jointing woodwork around plumbing fixtures? (d) for jointing slate slabs?

(388) (a) What class of a shut-off valve is best adapted for placing on a water pipe? Give your reasons.

(b) What class of faucets should be used to supply water under heavy pressure to a kitchen sink? Give your reasons.

(389) (a) What is a flux? (b) Describe its use. (c) What flux would you use to join clean zinc?

(390) Describe briefly with sketch how you would solder together two pieces of 16-ounce sheet copper tinned on one side only. The seam must be strong and water-tight.

(391) (a) Give a sketch of a wiped joint on a $1\frac{1}{4}$ -inch water pipe; (b) of a joint upon a $1\frac{1}{4}$ -inch waste pipe. (c) Describe how each is prepared and secured for wiping in a horizontal position on the bench.

(392) Explain what must be carefully guarded against in the preparation of branch joints.

(393) Describe how you would wipe an upright corner seam in a lead-lined tank.

(394) Why is air mixed with the gas before its combustion at the orifice of the ordinary compound blowpipe?

(395) What are pipe tacks? What are they used for, and of what material should they be made?

(396) What do you understand by 20-oz. sheet copper, and what is the cost of a sheet of such material 60×96 inches at the rate of 28 cents a pound? Ans. \$14.

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(397) What is plumbers' soil? How can it be applied to the greasy surface of sheet lead?

(398) Two tanks, A and B, set on the same level, are joined together by a pipe connecting their bottoms. Water is pumped into tank A and flows through the pipe into tank B. Describe clearly what attachment can be used to prevent the water in B from returning to A.

(399) How can chloride of zinc be made?

(400) Give a description of the sweating of a seam while being soldered.

(401) Describe the process of "getting up the heat" on an underhand wipe joint.

(402) What is a splash stick? Explain its use.

(403) A rectangular house tank has a seam in each inside angle. State how you would wipe the seams, where you would begin, and where end.

(404) How can you tell when too much gas is admitted to the compound blowpipe flame, and what would be the result if such a flame were used for brazing?

(405) How should leaden waste pipes 2, 3, and 4 inches in diameter be supported when in a vertical position? How when in a nearly horizontal position?

(406) Describe briefly how the malleability and ductility of zinc are affected by first increasing the temperature from 40° F. to 275° F., and then from 275° F. to 400° F.

(407) Describe an ordinary and a flush fitting for wrought-iron pipe, and mention upon what the tightness of the joint in each depends.

(408) A concrete basement floor has a drain pipe to convey water spilled upon it to the sea. During very high tides sea-water backs up the drain and floods the floor. Describe clearly, with sketch, showing all attachments, the arrangement you would use to avoid these floods.

(409) Why is brass or copper work tinned before it is soldered?

(410) How can you tell when the copper bit is too cold to continue soldering and do good work?

(411) Describe the process of wiping, and at what part of the operation of joint making it should begin.

(412) What class of branch-joint is best adapted for horizontal waste pipes? Give your reasons.

(413) Give a sketch in section through a locked, or double, seam in a sheet-copper tank lining.

(414) How can you distinguish the presence of too much air in the blowpipe flame, and how does it affect the flame?

(415) What is the objection to the supporting of leaden pipes at intervals in their lengths, and how are such pipes affected by periodical flows of hot water through them?

(416) What is galvanized sheet iron, and what is the weight of a sheet 30×72 inches, whose number by the Birmingham wire gauge is 22? Ans. 19.80 lb.

(417) Describe the difference between packed and ground unions. What kind of a union would you use for 3-inch wrought-iron pipes?

(418) Describe an arrangement that may be attached to a kitchen boiler to prevent a rupture by overpressure, or its collapsing from a partial vacuum formed within it.

(419) How would you tin a soldering bit with sal-ammoniac as a flux?

(420) Describe clearly, with sketch, how you would join together two pieces of 7-pound sheet lead.

(421) Describe two methods of finishing off a wipe joint. What dangers are connected with them?

(422) Describe a flange joint and state how you would wipe one in position against a vertical wall finished with oak wainscoting.

(423) Describe the method of preparing sheet-copper seams (tinned) for wiping, supposing that the tank iron is to be used.

(424) What is the color of the blowpipe flame when doing its best work ?

(425) Describe a common way of securing wrought-iron pipes in position.

(426) Explain the use of the burr in riveting operations, and on what class of work is it most commonly used ? Also state what class of rivet is best adapted for riveting the seam of a wrought-iron cylinder subjected to heavy water pressure.

(427) What flaws in cast-iron pipes are often the result of casting the pipes in a horizontal position ? How can the flaw be detected without cutting the pipe ?

(428) A building is to be supplied with water from a reservoir situated at an elevation of 325 feet above it. The pressure desired within the building is 25 pounds per square inch. Describe an arrangement that can be placed on the pipe to accomplish this end. (Use no intermediate tanks.)

(429) How will the tinning on a soldering bit be affected by heating the bit to redness ?

(430) What do you understand by floating a seam ? What class of soldering iron is best adapted for floating a seam on sheet lead ?

(431) Mention two advantages obtained by the rapid cooling of a joint when wiped ; also how the cooling is usually accomplished.

(432) Describe briefly the process of preparing and wiping a brass ferrule on a four-inch lead pipe. Show by a sketch the connection as it appears when finished.

(433) What grade of sheet copper or sheet lead would you use to line a rectangular house tank 6×5 feet, and 4 feet deep ?

(434) Describe briefly the process of brazing a butt joint on two pieces of sheet copper $\frac{1}{4}$ inch thick.

(435) What kind of a hanger or clamp would you use to secure brass tubing to the walls of a kitchen, and why ?

(436) Calculate the weight of the following pieces of pipe: (a) One piece of $\frac{3}{4}$ -inch (inside diameter) A A lead pipe, 26 feet 6 inches long; (b) one piece of $1\frac{1}{2}$ inch waste pipe 8 feet 9 inches long; (c) one piece of $\frac{3}{8}$ -inch A A block tin pipe 37 feet 3 inches long.

Ans. $\left\{ \begin{array}{l} (a) \text{ 92.75 lb.} \\ (b) \text{ 17.5 lb.} \\ (c) \text{ 9 lb. 5 oz.} \end{array} \right.$

(437) Describe briefly how you would proceed to make a right-angle bend in (a) a 4-inch lead waste pipe; (b) a $1\frac{1}{2}$ -inch lead waste pipe; (c) a $\frac{3}{4}$ -inch A lead pipe; (d) a $1\frac{1}{4}$ -inch thin seamless drawn brass tube; (e) a 2-inch wrought-iron pipe; the radius of the curve to be 5 times the diameter of the pipe.

(438) A piece of copper, a piece of lead, and a piece of tin are heated to 700° F. What will be the result, and why?

(439) (a) What is the object of soiling metals before joining them with solder? (b) About what width of soiling is required for wipe joints, and (c) what for copper bit work?

(440) (a) Describe clearly how you would float a joint around a 2-inch lead waste pipe in a horizontal position. (b) What must be guarded against in such work?

(441) Explain the use of mirrors in joint wiping.

(442) (a) Describe with sketch a collar for upright joint wiping. (b) Of what material should it be made, and why?

(443) What are solder dots? Explain their use and how far apart they should be spaced in the tank in Question 433.

(444) (a) Show by sketch and written explanation the method of joining cast-iron soil and waste pipes. Give the names of the different parts of the joint.

(b) What grade of cast-iron pipes would you use for the soil, waste, and vent piping of a building 80 feet high above the curb?

(445) A 5-inch cast-iron pipe runs vertically against a stone wall from the basement of an eight-story building to above the roof. Show by sketches how the pipe should be supported.

(446) A bundle of $1\frac{1}{4}$ -inch (nominal diameter) wrought-iron pipe of standard dimensions weighs 169.35 pounds. How many lineal feet of pipe in the bundle? Ans. 75.

(447) Describe clearly the difference in construction of a plug cock and a compression cock, and state whether you would use a ground key bibb or a compression bibb for drawing off water under a high pressure. Give your reasons.

(448) What is the composition and the temperature of fusion of (a) soft spelter? (b) of plumbers' solder (ordinary)?

(449) How would you prepare copper, brass, and iron to receive solder? What flux would you use, and state what grade of solder is best adapted to such work when the copper bit is used?

(450) Describe clearly with sketch how you would prepare, and join together with the copper bit, two pieces of $1\frac{1}{4}$ -inch waste pipe placed in an upright position.

(451) In wiping a joint upon a large lead pipe having both of its ends open to the atmosphere and one end higher than the other, what would you do to prevent an undue loss of heat, and how could you maintain a working heat without trusting entirely to that emitted from the hot solder?

(452) (a) Explain the process of soft soldering with the mouth blowpipe. (b) How can you tell when the flame is giving the best results?

(453) Describe the merits of sheet block tin for covering woodwork around plumbing fixtures.

(454) Describe the method of running lead into horizontal spigot and socket joints.

(455) Show by sketch how the pipe in Question 445 could be securely supported with pipe rests if it were run in a pipe chase.

(456) (a) Explain briefly the difference between butt and lap-welded wrought-iron pipe. (b) What sizes of the pipes are butt welded and which lap welded?

(457) What is liable to happen when a spring cock is attached to a system of piping? Give your reasons.

(458) Describe clearly how you would proceed to make 10 pounds of plumbers' fine solder. State the weight of the ingredients.

(459) What precautions must be taken in soldering lead or tin?

(460) Show by sketch how you would connect a lead water pipe to the branch of the T in Fig. 151, Art. 691, supposing that the pipes *B*, *B* are run vertically. Give written explanation, stating the names of the different parts.

(461) Describe the method of preparing a T branch-joint for wiping.

(462) For what class of work is the mouth blowpipe flame best adapted? Why?

(463) Explain how outside and inside corners can be worked on sheet block tin.

(464) (*a*) Describe with sketch the method of joining a lead waste pipe to a cast-iron pipe. (*b*) What class of fittings should be used for wrought-iron soil, waste, and drain pipes? Give your reasons.

(465) What is the safest method of fastening a bolt to a marble slab in such a way that a hole will not be made through the slab? Give your reasons.

(466) Describe the difference between seamless drawn and brazed brass tubing. Which is the stronger?

(467) A storage tank is to be filled with water, and the water-line is to be kept nearly uniform without overflowing the tank. Describe an automatic-acting cock suitable for the purpose.

(468) Suppose that while working on a job some brass filings should get into your wiping solder; what would be the result, and how would you remedy it?

(469) What is the essential requirement of the soldering iron as regards its weight?

(470) What is an overcast joint; how is it made, and what is it generally used for?

(471) Draw to a scale of full size two sections of a wiped $\frac{3}{4}$ -inch T branch-joint, the lead to be $\frac{1}{4}$ inch thick.

(472) What metals are most commonly used for lining wooden house-tanks?

(473) (a) What are hard solders and what are they used for? (b) What is the name given to this class of soldering?

(474) Describe with sketch how a 2-inch lead waste pipe should be joined to a 4-inch earthenware pipe.

(475) Upon what does the stiffness and durability of a calked joint depend?

(476) (a) Describe a cast-iron soil pipe, and explain the difference between plain and coated pipes. (b) Mention a suitable coating and how it should be applied.

(477) How would you attach a globe valve to a pipe, and explain the chief objection to it?

(478) Distinguish between coarse and fine solder. If the solder is too coarse, how would you make it finer?

(479) How is heat transmitted from the copper bit to the metals to be joined? Explain the use of tinning a copper bit.

(480) What are the principal points to be considered in joint wiping?

(481) (a) Describe clearly how you would prepare the lead lining in a tank for a wiped seam.

(b) Describe briefly the process of securing and wiping a $\frac{3}{4}$ -inch T branch joint in the horizontal position.

(482) (a) What class of earthen pipe should be chosen to convey sewage? (b) Should earthen drain pipes be laid in made ground? Give reasons. (c) What objection is there to running an earthen drain pipe near a well?

(483) Describe an apparatus suitable for brazing medium-sized articles, such as 1-inch pipes, etc.

(484) How should a copper roof leader be connected to a cast-iron pipe in a building?

(485) Why should the burr be removed from the cut end of a wrought-iron pipe? Name and describe the method and tool used in this operation.

(486) (a) Describe a vitrified earthenware drain pipe and state the use of the glaze upon it.

(b) What is the effect of intermittent discharges of steam or very hot water into a cast-iron drain pipe, and of what material should a drain or soil pipe be made to successfully withstand the action?



PLUMBING AND DRAINAGE.

(ARTS. 828-963.)

EXAMINATION QUESTIONS.

(487) After a street main has been emptied for repairs, and the water again turned on, it is found that hot water drawn from faucets supplied by that main is milky in appearance, but soon clarifies from the bottom up. Explain the cause of the phenomenon.

(488) Explain clearly how the expansion pipe from a kitchen boiler which is supplied with water from a tank on the top floor can be employed to prevent the water from boiling in the kitchen boiler.

(489) Explain clearly how the water in a large boiler may be heated by steam from the house-heating system. What should be furnished to heat the water when the heating system is not in use?

(490) Explain briefly how porcelain wash bowls are secured to marble top slabs, and how the junction is made water-tight; also state what height the slabs are usually set above the floor.

(491) Explain the principal objection to the side outlet closet.

(492) How and from what source are modern water-closets flushed? What head is required for a good flush, if a $1\frac{1}{4}$ -inch flush pipe is used?

(493) Show by sketch a common round wash bowl with overflow horn connected to a bottle trap, and state what constitutes the seal of the bottle trap.

(494) Explain how a 3-inch cast-iron waste pipe stack

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should be continued up to and through a flat tin roof. How is the intersection with the roof made water-tight ?

(495) What are air chambers used for ?

(496) Suppose that water becomes saturated with air while in an open reservoir and is then conveyed by pipes to a point where it will be subject to a pressure of 88 lb. per sq. in. by the gauge, how much more air can it then absorb ?

Ans. 24% of its volume.

(497) Which is the more safe, a cast-iron water-back or a copper pipe fire-box coil ? State your reasons.

(498) Of what material should storage tanks which are exposed to the weather be made ? Explain the construction of such tanks and state if it is necessary to line them.

(499) Describe clearly how a basin cock should be attached to a marble slab, and how the slab should be finished to prevent water from soaking through the holes for the cocks, etc.

(500) Explain briefly the action of the siphon jet closet, and state from what it derives its name.

(501) Describe briefly the action of a siphon tank, and explain its advantage over the plain flushing tank.

(502) What class of a trap would you place under a bath that is very seldom used ? State your reasons.

(503) If the soil and waste pipe stacks are continued through the roof, is it proper to ventilate the branch pipes ? If so, how and why ?

(504) What should be considered in selecting a lining for tanks to contain drinking water ? What metal is commonly used in lining wooden tanks ?

(505) A long line of 1-inch lead pipe is run between the city main, and a lever-handled ground key cock is wiped on its extreme end. (a) Explain what will result from rapid opening and closing of the draw-off cock. (b) How would you guard against it ?

(506) What capacity of boiler and what size of water-back would you put in an ordinary dwelling having two baths, two basins, one set of tubs, and two sinks, supposing that water is plentiful?

(507) Describe clearly the principal points to be considered in the construction of a rectangular wooden house tank, and explain with sketch how a tie-rod can be used to prevent the vertical posts from bulging near their centers.

(508) Mention two great objections to the use of plunger closets.

(509) Mention two methods of furnishing water to a plunger closet without the use of overhead flush tanks. State the objections to such methods of flushing closets.

(510) Should bell traps be used in drainage systems? Why?

(511) What is the proper point at which to attach a back-vent pipe to a vent stack? Give your reasons.

(512) If a water storage tank is located on the top floor of a building, what provision should be made to prevent damage to the building by leakage from the tank?

(513) Explain briefly the cause of hammering noises in a kitchen boiler.

(514) Explain the difference between single and double-riveted boilers. What class of work are they, respectively, adapted for?

(515) How is water admitted to a house tank (*a*) from a street main? (*b*) from a pump? (*c*) from roof gutters?

(516) Show by sketch a copper-lined wooden bath-tub of the common form, fitted up complete with pipe connections for hot and cold water, plug and socket waste connection, and overflow horn. Use a running trap, and place a lead safe under the bath.

(517) What particular point must be considered in connecting the hot and cold water pipes to showers, sprays, etc., so that the bather may not be scalded ?

(518) Explain clearly what happens when the handle of a pan closet is raised.

(519) What class of flushing apparatus may be used to automatically flush a urinal every five minutes? Explain how it operates.

(520) Should refrigerator waste pipes join the drainage system? If not, is there any use of trapping refrigerator waste pipes? Give your reasons.

(521) What pitch should be given to a 2-inch, a 4-inch, and a 6-inch drain pipe in order to obtain nearly the same velocity in the flow of sewage through each?

(522) What precautions should be taken in connection with the use of tanks for the storage of drinking water?

(523) Show by sketch how you would connect a $1\frac{1}{4}$ inch galvanized-iron pipe to an 8-inch cast-iron street main, using a $\frac{3}{4}$ -inch corporation cock. Explain the use of the different parts and the materials of which they are made.

(524) Show by sketch the most common method of connecting up a vertical kitchen boiler 5 ft. long and 15 in. in diameter. State the names and duties of the several pipes.

(525) What are overflow and telltale pipes? When, how, and at what points should they be connected to a tank? State also the use of a standing overflow pipe fitted with plug and socket attachments on the bottom of a tank.

(526) Describe a combination bath cock. Where should it be attached and why?

(527) Explain the construction of a hopper closet, and mention how the flush should be applied.

(528) Suppose that ten washout closets are set side by side in a row, and a large water tank placed 6 feet above

them extends the full length of the row. (a) What arrangement may be used to automatically flush each closet separately after it has been used as a water-closet? (b) For what class of buildings is this method of flushing closets most suitable?

(529) (a) Should a trap be used for each fixture, and if so, where should it be placed? (b) Where should rain-water leader traps be placed, and what should be considered regarding their seals?

(530) State the objections to large pipes for drainage work.

(531) State the chief reasons why buildings should be disconnected from sewers and cesspools.

(532) (a) What is a street washer? (b) Explain its use and state where the shut-off cock should be placed, and why.

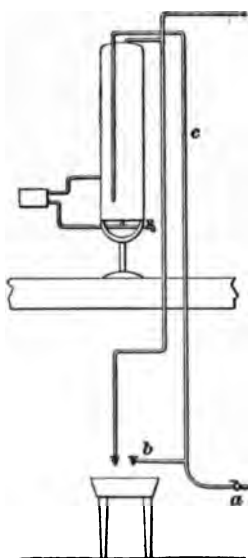


FIG. 4.

(533) Suppose that in Fig. 4 the stop-cock *a* on the cold-water pipe is shut and the sink-cock *b* is opened for the purpose of emptying the pipe *c*, and fire is allowed to remain burning in the range; what is liable to happen? How would you guard against it?

(534) Describe the principal points to be considered in selecting the location of sinks, and in fitting them up. About what height should they be set above the floor?

(535) What is the chief objection to a standing overflow and waste pipe when located within the bath; also, to cocks or valves projecting inside the bath?

(536) Suppose that a water-closet must be placed in a back yard and that it will be subject to freezing weather; what class of a closet should be used? Where should the trap be placed, and why?

(537) Describe the construction and operation of a set of latrines. What class of work are they commonly used upon?

(538) If a considerable quantity of grease in a molten state flows into the waste pipe of a kitchen sink, along with the hot water, how will the waste and drain pipes be affected? How may the difficulty be overcome?

(539) What depth is the water in a drain pipe when the maximum velocity of flow is obtained? Explain the cause of this.

(540) What is an anti-siphon back-vent, and what is it used for?

(541) What should be avoided in notching beams? If it is necessary to notch them, where should the notches be cut? Give reasons.

(542) Show by sketch how a vertical boiler may be fitted up so that hot water can be drawn at the fixtures before the boiler becomes heated. What objection is there to this method of connection?

(543) Describe two forms of copper pantry sinks. How are they supported?

(544) Describe with sketch how a standing waste and overflow can be applied to a bath without occupying space inside the bath. Show the bath full to overflowing.

(545) What are the chief objections to (a) wooden wash tubs and (b) slate tubs?

(546) According to the latest theory, what should be the size and shape of a closet seat? Give reasons.

(547) Describe a trough closet constructed to be flushed automatically.

(548) How can the water seal of a trap be protected against siphonage?

(549) Describe how vitrified earthen drain pipes should be laid and joined. What precautions must be taken?

(550) What is the objection, in very cold districts, to the use of the cowl or ordinary pattern of vent cap as a covering for vent pipes, and what precautions have to be taken in dealing with this matter?

(551) Describe an air lock in a pipe. Explain its effect when water flows through the pipe with a very low velocity.

(552) Suppose that a wash basin on the second floor is located a considerable distance from the boiler on the first floor, and that the cold water lying in the pipe must be drawn off before hot water can be obtained at the basin; how can the piping be so arranged that hot water will flow from the faucet at the instant it is opened?

(553) (a) Where is the standing waste usually located outside the French style of bath? (b) where in the Roman style?

(554) Show by sketch how the lead waste pipe of a set of three porcelain tubs should be run. The waste water must discharge into a 3-inch cast-iron pipe stack at the back of the left-hand tub. Use a $\frac{3}{4}$ S round pipe trap, and back-vent it into the stack.

(555) Describe the proper method of joining an all-porcelain closet to a lead soil-pipe branch. What precautions must be taken in making such a joint?

(556) Suppose that water is scarce, and a continuous flow can not be obtained to flush a urinal, what do you consider to be the next best method of flushing it? Provide for carrying away floor drippings.

NOTE.—Periodical flushing tanks must not be used.

(557) Suppose that an old pan closet has to be removed and a front outlet washout closet put in its place; what alteration must be made under the floor before setting the new closet?

(558) Explain the use of inspection pieces and hand-holes. State at what points of a drainage system they should be attached.

(559) What are the names of the instruments used to find the pressures on (a) the pipe supplying water to a kitchen sink? (b) the suction pipe of a pump which is placed 20 feet above the water to be raised? (c) If the instrument applied to the pipe in (a) indicates 60, and the instrument applied to (b) indicates 11, what is the difference in pounds per square inch between the pressures as indicated by the instruments? Ans. (c) 71 lb.

(560) Describe briefly the cause of water circulation by the application of heat.

(561) (a) Under what circumstances are horizontal kitchen boilers mostly used? (b) Can you observe any defects in Fig. 5, which

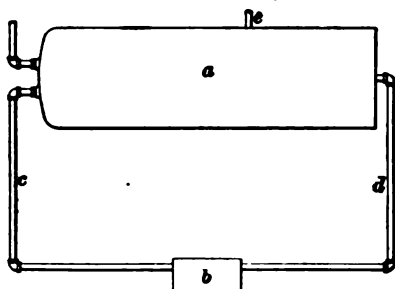


FIG. 5.

shows a common vertical boiler *a* connected in a horizontal position to the water-back *b* by the pipes *c* and *d*; the pipe *e* furnishes hot water to the fixtures and the other pipe feeds the boiler with cold water; if so, state them

and show by sketch what alterations you would make to obtain the best results?

NOTE.—You may tap the boiler at any point, but the water-back must remain the same.

(562) (a) What are the objections to wood, steel, and enameled iron as materials for sinks? (b) Describe the chief merits of glazed earthenware or porcelain sinks.

(563) How and at what point is the hot and cold water usually permitted to enter (a) a porcelain French bath? (b) a porcelain Roman bath?

(564) Where should the faucets for laundry tubs be placed (a) when the tubs are always open, as in a laundry? (b) when they are fitted with covers and closed when not in use, as in the kitchens of apartment houses? Give your reasons?

(565) On what part of the outlet to a water-closet should the junction between porcelain and metal be made? Give reasons.

(566) Define sewage and sewer gas. Explain how the latter is generated, and state the diseases that are liable to result from inhaling the gases.

(567) Explain the use of a local vent, and state what must be considered in running the vent pipe.

(568) How can a small stream of water, constantly flowing, be made to properly and automatically flush a long line of drain pipe, supposing that the source of the stream is 10 ft. higher than the head of the drain? Describe the operation of the apparatus required.

(569) (a) To what height will water rise in a building if the pressure in the supply pipe located in the cellar of the building is 38 lb. by the gauge? (b) Would it be advisable to supply a fixture from this pipe if its vertical height above the gauge is 85 feet? Give reasons.

Ans. (a) 87 ft. $6\frac{1}{2}$ in., nearly.

(570) How does pressure affect the boiling point of water?

(571) Suppose that a building is to be supplied with water from two separate sources; for instance, a tank placed on the top of the building which will furnish hot and cold water to the upper floors, and the street mains which will furnish hot and cold water to the lower floors. One water-back must heat the water for the entire building. (a) What class of boiler would you use, and why, and of what material should the boiler be made? (b) Give a sketch of the boiler and the pipe connections. Show by arrows the currents of circulation.

(572) What constitutes a good water-closet?

(573) (a) Should the flush-pipe connection to a porcelain water-closet bowl be rigid or flexible? Give reasons.

(b) Mention a common connection that will compensate for any ordinary change of position of the flush pipe or closet, due to the settlement of a building, etc.

(574) What is a trap? Explain its use, and show by sketch what constitutes the seal of a round pipe S trap.

(575) Of what material are the waste-pipe branches to fixtures usually made, and why?

(576) What should be considered in selecting the location of the fresh-air inlet to a drainage system? State how a blow-back can occur at the inlet.

(577) How is water affected by using pipes made of (a) black iron? (b) lead? (c) galvanized iron? (d) lead lined with block tin?

(578) (a) A 60-gallon kitchen boiler is filled with water having a temperature of 40° F. What will be the cubical expansion of the water when its temperature is increased to 210° F.? (b) If the expansion can only travel in one direction, that is, up a vertical pipe $1\frac{1}{2}$ in. in diameter, how high would the water rise in the pipe?

Ans. $\left\{ \begin{array}{l} (a) \text{ 603.1 cu. in.} \\ (b) \text{ 28 ft. } 5\frac{1}{4} \text{ in., nearly.} \end{array} \right.$

(579) Explain clearly how the sediment pipes should be attached to a double boiler, and where the sediment cocks should be placed. Give reasons.

(580) (a) Describe the various wash-basin overflows and waste pipes in common use. (b) Describe a stand-pipe waste, and explain its advantages over the ordinary waste plug.

(581) Describe briefly the construction of a front outlet washout water-closet, and state the proper depth of water seal in the trap; also, proper depth for water in basin. Give reasons.

(582) (a) What constitutes a good flush in a water-closet? (b) How can the efficiency of a flush be approximately ascertained?

(583) What are the chief objections to the use of bottle traps? Should such traps be used for water-closets or urinals? Give reasons.

(584) Fig. 6 shows a washout closet *a* and a copper-lined bath *b* connected to a soil-pipe stack *c*, the end *d* of which is carried straight up to and through the roof. No other fixtures discharge into the stack. Show by sketch any alterations you may consider necessary to make a proper job of the whole. The closet and bath must remain in the same position, and the pipe *c* must run down between the door *e* and partition *f*.

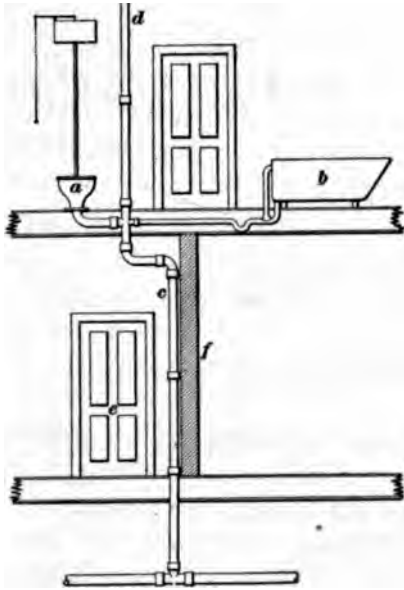
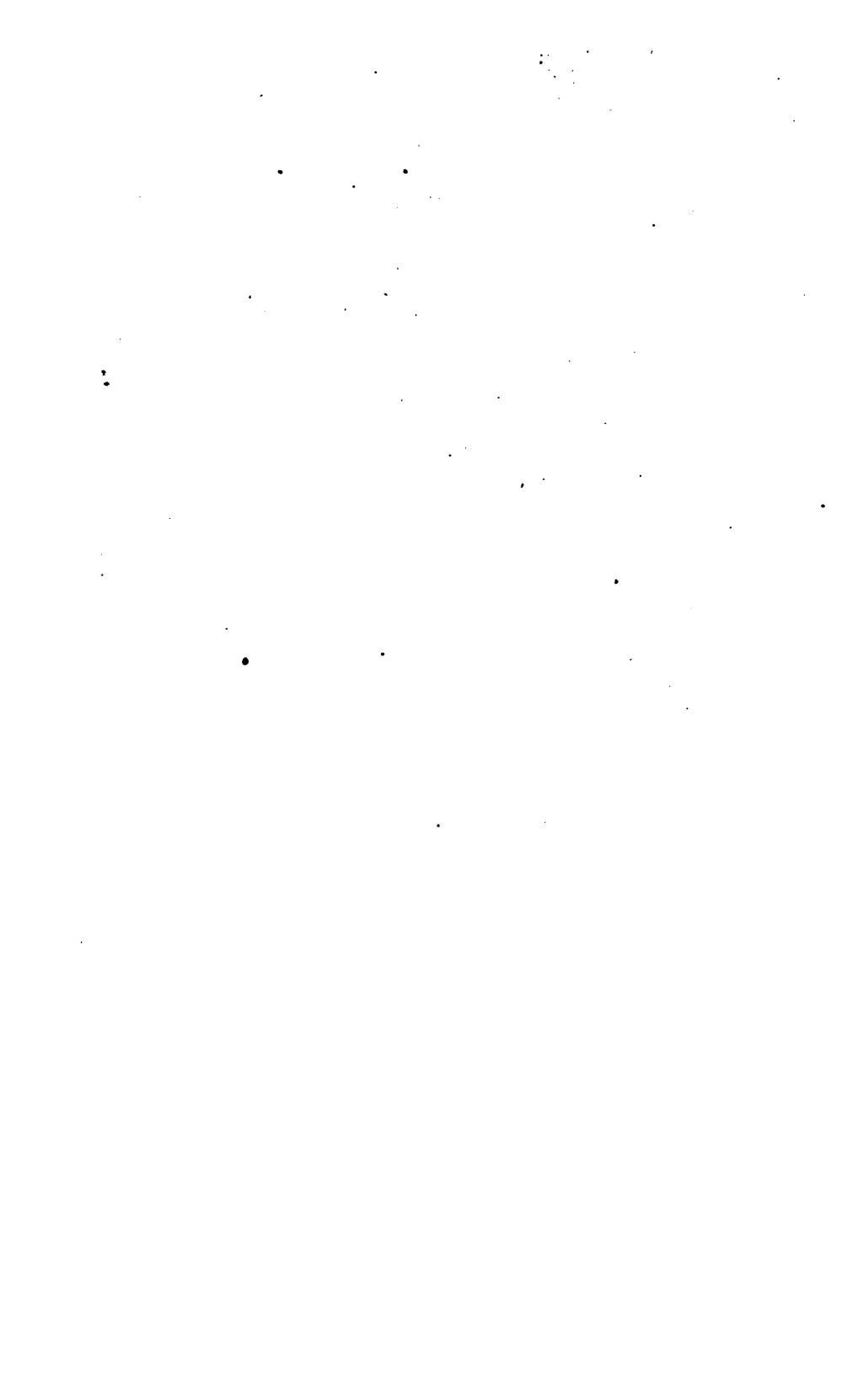


FIG. 6.

Back vent into *d* and mark the sizes of the pipes.



PLUMBING AND DRAINAGE.

(ARTS. 964-1052.)

EXAMINATION QUESTIONS.

(585) (a) What should be provided to prevent the fire in the tubes of a burning machine from exploding the machine? (b) Where is it usually placed?

(586) (a) How would you diminish an air and hydrogen blowpipe flame? (b) How would you extinguish it?

(587) Describe the hydrostatic test as applied to house-drainage systems.

(588) Describe a frost burst (a) in a lead pipe; (b) in an iron pipe. (c) Will iron pipes, being stronger than lead pipes, better resist the action of frost?

(589) What should be carefully considered before discharging crude sewage into (a) streams? (b) into the sea?

(590) Is there any objection to a velocity of 8 feet per second in brick sewers? Give reasons.

(591) A rapidly flowing stream of good drinking water runs within 300 feet of a country building which is situated 60 feet above it vertically; (a) explain how you would arrange a self-acting machine which will raise water to the building. (b) What causes the water to rise to the building? (c) How would you fit up three of these machines so that they may, separately or together, raise water to the building? (d) What shut-off valves are necessary?

(592) If there is any danger of hot water entering a water meter, what must be considered and guarded against?

(593) How may water, which has grown stale and "flat," be freshened and made brisk again? What is the process called?

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(594) What kind of seams should be made in a tank which is built for the storage of acids, the tank lining being 7-pound sheet lead? Give your reasons.

(595) (a) How should the air supply which is necessary to operate a lead burning blowpipe be furnished? (b) What are the necessary requirements of a good blast?

(596) Describe the essential part of the process of lead burning.

(597) Upon applying the hydrostatic test to a system of cast-iron drains and soil pipes, the following defects were observed: (a) A joint leaking slightly around the calking; (b) a leak due to a split socket; (c) a leak from a split in the pipe; (d) a flaw in the casting; how should they be remedied?

(598) The main service pipe under the sidewalk, and in the cellar of the building where it runs along the face of a brick wall, is frozen; explain how you would proceed to thaw it. Describe any apparatus used.

(599) What do you understand by the "separate" system of sewerage?

(600) (a) Mention a suitable fall for a street sewer. (b) What should be attached to a sewer which has a fall of 1 in 600 to prevent solid matter from accumulating?

(601) (a) What particular point should be attended to when setting a single-acting windmill pump, so that the work upon the mill will be as easy as possible and the flow of water uniform? (b) If it is neglected, what will happen?

(602) Explain how you would test a water meter.

(603) (a) What should be guarded against when roof water is collected and stored in tanks or cisterns for drinking purposes? (b) How should dust, bird excreta, etc., on the roofs be prevented from entering the storage tanks or filters?

(604) How is the operation of lead burning performed? State what must be considered regarding quality or composition of the flame.

(605) What is a mixing pipe on a lead-burning apparatus? Explain its use, and state how the right proportions of air and gas are obtained at the blowpipe.

(606) Upon what does the strength of a lead-burned seam chiefly depend?

(607) (a) Describe the smoke test, and explain its particular advantages. (b) At what stage of the work should the smoke test be applied? (c) What pressure of smoke should be employed if a running trap is used on the drainage system?

(608) (a) Explain how waste pipes from kitchen sinks are liable to become choked. (b) What should be provided for easy access to clear chokage? (c) How should a lead waste pipe which is choked be cleared?

(609) What do you understand by the combined system of sewerage?

(610) When draining carriage house or stable floors, what precautions should be taken to (a) prevent the entrance of sewer gases? (b) to prevent straw, etc., from choking the drains?

(611) (a) Describe briefly a single-piston hot-air engine, adapted for low-duty pumping. (b) What are its advantages as a pump for domestic purposes?

(612) What considerations govern the size of water-supply pipes?

(613) What are the chief points to be considered in selecting a good filter (a) in regard to the velocity of flow through the filtering medium? (b) in regard to the cleansing of the filtering medium?

(614) Describe a hydrogen gas generator, and explain briefly how the gas is generated and stored in the machine; also, what prevents an excess of gas pressure in the generator.

(615) (a) Mention a danger attending the use of a mixing pipe. (b) Where are the adjusting cocks placed in the safest forms of lead-burning apparatus?

(616) (a) Explain the use of the lead stick in lead burning. (b) On what class of seams is it commonly used?

(617) (a) Describe the peppermint test, and explain how it can be employed without the aid of a machine. (b) How are leaks detected by this test?

(618) How would you proceed to ventilate a dark water-closet apartment, a jet of gas being used to light the apartment? No air-shafts are in the vicinity.

(619) Give a sketch, showing the proper proportions, of a sewer suitable for removing house sewage and large volumes of storm water (combined). What are the advantages of this shape over the ordinary round sewer?

(620) A cellar is occasionally flooded with surface water. The cellar floor is 2 feet below the level of the city sewer. The water supply to the building is abundant, and the pressure is high. (a) Explain the best method you know of for automatically discharging this cellar water into the sewer. (b) What operates the machine, and what causes the cellar water to move?

(621) What class of hot-air engine would you use to raise water from a well 75 feet deep to a house tank 100 feet above it, if the man in charge of the pump is a gardener? Give your reasons.

(622) Draw to a scale of twice the size of the cut (Fig. 361, Art. 1029) the fixtures shown. Let the 1-inch water-supply pipe enter from the right instead of the left, as shown in the cut, and take off branches to the different fixtures. Mark diameters of pipes.

(623) Describe briefly, with sketch, a simple form of an underground filter for removing mechanical impurities from roof water before it flows into an underground brick cistern.

(624) What is the object of blowing the air out of the generator of a lead-burning machine before allowing gas to accumulate? How is it accomplished?

(625) (a) Does moisture ever gather in the rubber tubes of a lead-burning machine? (b) If it does, how will it affect the blowpipe flame?

(626) Describe three forms of lap joints in sheet-lead work, and explain how each form is burned with the air and hydrogen blowpipe.

(627) (a) How should water-supply pipes be run in buildings situated in cold climates? (b) If there is danger of a water pipe being frozen by being run in a cold place, explain what should be done to protect the pipe.

(628) (a) Mention three common methods of disposing of sewage matter from buildings. (b) What kind of pipe is usually employed for sewer connections to ordinary residences? State its diameter and how it should be laid.

(629) (a) At what point should the house drain join an egg-shaped sewer? (b) What is the "invert" of a sewer?

(630) What advantage has the chain pump over the piston pump for raising water out of shallow wells or cisterns?

(631) (a) How are the leather packings which make the cylinders of the Rider compression engine air-tight prevented from being burned by the hot air? (b) What is the use of the automatic air-supply valve on the cooling cylinder? (c) Explain the use of the regenerator plates. (d) What will result if the engine pistons are carelessly oiled? (e) What particular points must be considered in setting the engine?

(632) What should be considered regarding the branches taken from a rising main to supply the different floors of a tall building, so that a uniform supply can be obtained for all the floors?

(633) Explain briefly the principal points to be considered in selecting the location of (a) kitchen sinks; (b) wash tubs; (c) pantry sinks; (d) bath rooms.

(634) (a) What kind of zinc is best adapted for making gas in the ordinary lead-burning machine? Give your

reasons. (b) How much zinc would be required to make about 40 cubic feet of hydrogen gas under the machine pressure? Ans. (b) 8 lb.

(635) Suppose that the gas generator and air holder of a lead-burning apparatus are charged; explain how you would proceed to start the blowpipe, and how you would know when you had the proper lead-burning flame.

(636) How should two pieces of lead pipe be prepared for burning in a vertical position? How is the blowpipe flame fed?

(637) What is the cause of a pipe being burst by frost? Why does not the ice form without bursting the pipe?

(638) (a) What are the chief objections to cesspools? (b) How do they affect wells in the vicinity? (c) What epidemics are liable to be caused by cesspools and wells being situated in the same stratum of earth, and near each other?

(639) What is the natural direction of the flow of sewer gas in a ventilated sewer, if its orifice of discharge and its highest ends are all open to the atmosphere, (a) during summer? (b) during winter?

(640) What precaution should be taken before entering a deep well? Give reasons.

(641) (a) What are water meters used for? (b) How and where should they be set?

(642) How may mechanical impurities be extracted from water?

(643) (a) Mention two objections to locating plumbing fixtures in rooms immediately over parlors, libraries, and dining rooms. (b) Above what rooms or places should they, if possible, be situated?

(644) (a) Does the generator of a lead-burning apparatus remain at a constant temperature or become warmer or colder while making hydrogen gas? (b) How does heat affect the making of the gas? (c) If a lead-burning machine

has been run a while and then allowed to cool down, what is liable to happen?

(645) What part of the air and hydrogen flame is most useful in lead burning? Give your reasons.

(646) (a) What are the principal points to be considered in lining a tank with sheet lead, if acids are to be stored in it? (b) How are the end sheets usually fitted and secured in place, acid-tight?

(647) (a) Explain how a pipe full of water may freeze and not burst. (b) Explain how a pint of water may freeze, and burst a pipe.

(648) If house sewage is to be discharged into a tidal river or the sea, what are the chief points to be considered regarding the arrangement of the sewer pipe?

(649) Should storm water and street washings flow directly into a sewer? Give reasons.

(650) (a) Describe briefly and clearly how water can be raised from a well, stored underground, and be maintained under a pressure suitable for supply to a building near it. (b) What are the advantages and disadvantages of the method?

(651) The last time the meter dial shown in Fig. 7 was read, it indicated 6,417 cubic feet; how many cubic feet of water have passed through the meter since that time?

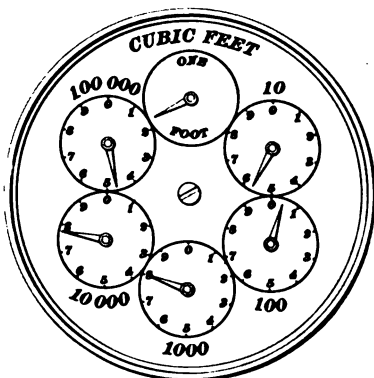


FIG. 7.

(652) What kind of charcoal is best adapted for use as a filtering medium? Give your reasons.

GAS AND GAS FITTING.

(ARTS. 1053-1218.)

EXAMINATION QUESTIONS.

(653) A service pipe discharges 185 cubic feet of gas per hour into the atmosphere from a street main having a pressure of 1.75 inches of water; what volume will be discharged per hour if the pressure in the main is increased to 4 inches of water?

Ans. 279.7 cubic feet, nearly.

(654) How many cubic feet of gas should pass through a meter before the pointers on the meter dial are changed from the position shown in Fig. 378, Art. 1080, to the position shown in the accompanying Fig. 8?

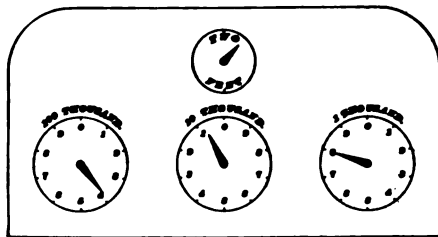


FIG. 8.

Ans. 26,600 cu. ft.

(655) What diameter of pipe should be used to supply 27 ordinary burners with coal gas, the length of the pipe being 97 feet, and the pressure of the gas 2 inches of water?

(656) Briefly describe the proving pump and the mercurial pressure gauge commonly used in testing gas-pipe systems.

(657) What is the principle upon which incandescent light is produced by means of ordinary gas?

(658) Describe briefly the construction and operation of an instantaneous water heater which uses gas as a fuel.

(659) What is about the proper height for side lights and hanging fixtures in an ordinary dwelling?

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(660) (a) What is the candle power of acetylene gas? (b) How many 5-foot batswing burners, consuming ordinary coal gas (16 c.p.), will be required to furnish as much light as that from a well-designed acetylene burner consuming 5 cubic feet of acetylene in the same time?

Ans. (b) About 15 burners.

(661) How many 5-foot batswing burners will be required to properly illumine an auditorium 65 ft. $\times$ 90 ft. and two balconies, each having 1,200 square feet of floor area?

Ans. 206 burners.

(662) (a) Mention the advantages and disadvantages of cast-iron pipe for underground gas pipes. (b) How should such pipes be protected against rust?

(663) How do you account for the fact that the water gauge pressure of ordinary illuminating gas is higher at the top than at the bottom of a tall building?

(664) Describe the operation of a water-sealed gas governor. What is it commonly used for?

(665) Explain how water accumulates in gas pipes; also, the effect of such accumulation upon the flow of the gas.

(666) Describe the "ether cup" and its use in testing gas pipes.

(667) Briefly describe the batswing burner.

(668) Mention the use of a "fire check" on atmospheric burners and explain how it operates as a check.

(669) (a) Mention a few precautions which should be taken while searching for gas leaks in a building. (b) Twelve parts of air and one of gas exist in the dark cellar of a building; is it safe to search for a leak in such an atmosphere with a naked light?

(670) Describe briefly the process of producing gasoline gas, commonly known as "air gas."

(671) What do you understand by the expression "candle power?"

(672) How would you run a $1\frac{1}{2}$ -inch wrought-iron service pipe through earth which is partly made up of ashes? How would you protect the pipe?

(673) The pressure of gas in the basement of a tall building is 1.25 inches of water. The density of the gas compared with air is .5. What will be the pressure in inches of water of the gas on the eighteenth floor, which is 220 feet above the basement? Ans. 2.85 inches of water.

(674) Describe the operation of a dry governor. Where is it commonly employed, and why?

(675) (a) In piping a building for the distribution of gas, how would you provide for condensation within the pipes? (b) Suppose that an unavoidable sag is made in one of the main lines in a cold place of the basement, how would you provide for accumulation of water of condensation there?

(676) What do you understand by the term "combustion of gas?"

(677) (a) Briefly describe the Argand burner, and state the most desirable pressure at which it should burn the gas. (b) Why is a chimney necessary for the Argand burner?

(678) (a) What are gas fixtures? (b) Distinguish between gas brackets and chandeliers.

(679) (a) How do you account for the flickering and jumping of gas lights? (b) How would you remedy the defect?

(680) How many U. S. gallons of gasoline of the best grade are required to furnish 15 c.p. gas to ten 5-foot burners for 100 hours? Ans. 22.5 gallons.

(681) Briefly describe the process of determining the candle power of a gas flame by the use of the Rumford photometer.

(682) What are the principal objections to lead, tin, and composition as materials for gas pipes in buildings?

(683) Explain briefly how gas pressures are usually determined and read; also, how the scale is laid out.

(684) Describe the chief difference between a common pressure governor and a volumetric regulator.

(685) If the meter *a* in Fig. 385, Art. 1093, is placed in the basement directly under the dining-room double window, and the gas fixtures all remain in the positions shown by this and the succeeding figure (386), show by drawings, the same size as those in these figures, how you would run the gas piping for the building, and mark the nominal sizes of the pipes upon your drawings. Allow for a 1-jet pillar light to be set on the newel post at the foot of the stairs.

(686) What are the principal products of the combustion of coal gas, and how are they formed?

(687) Describe the principles of the regenerative lamp, and explain the construction and operation of a gas lamp which operates on this principle.

(688) What must be considered in the construction and maintenance of the keys of gas fixtures as regards the safety of the occupants of the building?

(689) Describe a service cleaner, and state the advantage of the air chamber.

(690) Briefly describe a gasoline gas "generator," and state how the air, in passing through the generator, becomes carbureted.

(691) Suppose that the sight-box diaphragm of a Bunsen photometer is 20 inches from the center of the candle flame and 80 inches from the center of the gas flame, when both sides of the diaphragm appear the same; what is the candle power of the gas?

(692) What "fittings" are best adapted for wrought-iron gas pipe work? Give your reasons.

(693) A mercury gauge indicates 7.5 inches of mercury; what pressure does this represent in pounds per square inch?

(694) Mention three prime reasons why gas governors should be employed on gas-distributing systems.

(695) Describe how house-service pipes should be run, and how connected to the street mains.

(696) Upon what does the temperature of a gas flame chiefly depend?

(697) Briefly describe the principles of an incandescent gas lamp of the Bunsen burner type.

(698) If you are requested to hang a chandelier in such a manner that it may be either swung or turned around, what kind of a joint would you make at the ceiling?

(699) (a) What are the principal causes of gas jets smoking? (b) How may they be remedied?

(700) (a) Where should gasoline gas generators be placed in respect to the building? Give reasons. (b) What must be considered regarding the temperature of the generator?

(701) Explain briefly how you would proceed to determine the c.p. of a gas flame by means of the Bunsen photometer having a star disk. What must be considered regarding the supply of gas to the flame?

(702) Upon what does the rate of the flow of gas depend?

(703) Explain briefly how you would proceed to determine the velocity of gas in a 6-inch street main.

(704) Would you consider pressure regulation or volumetric regulation best adapted for the proper distribution of gas in a tall building? Give your reasons.

(705) Describe briefly the most important points to be considered in setting and connecting up (a) wet meters; (b) dry meters.

(706) Describe briefly how the combustion of gas takes place in an "atmospheric burner."

(707) (a) Describe the difference between the flame of the Bunsen, and the flame of the Fletcher burner. (b) Which of these burners requires the larger air inlet? Give reasons.

(708) (a) Describe the construction of two different forms of sliding chandeliers. (b) Is water a suitable liquid for use in sealing chandelier tubes? Give reasons.

(709) (a) Briefly describe the process of making coal gas. (b) What are the impurities, and how are they generally separated from the gas?

(710) Describe the operation of an air pump commonly employed to supply air to gasoline gas generators.

(711) The water in a certain kitchen boiler is heated by a copper-pipe coil submerged in the water in the boiler. The products of combustion from a gas flame pass up through the coil and escape to the atmosphere from its upper end; explain how it is, when the gas is burning and the water is cold, that water trickles down the coils and spills upon the floor.

(712) How does the volume of gas delivered by a pipe of any given size vary with the length of the pipe, the pressure and density of the gas remaining the same.

(713) It is found that a certain gas-service pipe delivers 750 cubic feet of gas under a pressure of 6 inches of water; what will the volume of this gas be when the pressure is reduced to 1 inch, the temperature remaining the same?

Ans. 759.2 cubic feet, nearly.

(714) What are the chief objections to the practice of "checking" a burner by cotton wadding, etc.?

(715) At what stage in the construction of a building should the gas-fitter begin his work?

(716) When the gas and air are heated before they reach the burner, the heat being obtained by the products of combustion, (a) what is the process called? (b) How does the "pre-heating" affect the intensity of the flame? Give your reasons.

(717) (a) How would you convert a Bunsen burner into a Fletcher burner? (b) What advantages would be obtained by the change?

(718) How are sun lights commonly ignited (neglect electrical methods)? Explain the use of the pilot light.

(719) (a) What is producer gas? How is it made? (b) What gases constitute the combustible part of producer gas, and in about what proportions do they exist?

(720) (a) Explain the use of a "mixing device" on a gasoline gas plant, and describe its operation. (b) State what class of burners must be used if the mixer is not employed.

(721) (a) What are shields used for in gas-fixturing work? (b) If an open burner happens to be 2 feet 6 inches from a ceiling, would you consider it necessary to use a shield?

(722) The length and diameter of a pipe and the composition of the gas remaining the same, how do pressure variations affect the volume delivered?

(723) Briefly describe the operation of a wet meter, and mention its disadvantages.

(724) Where is the proper place to connect a pressure regulator so that it will control the entire building; and, under such conditions, to what pressure should the meter be regulated so that it may operate correctly?

(725) What are the most important points to be considered in securing "drops" for hanging fixtures?

(726) Which part of the process of combustion produces light?

(727) What particular features should be considered in the design and construction of gas stoves as regards utilization of the heat in the products of combustion?

(728) (a) What is the principal object of enclosing gas flames with "globes?" (b) What should be the minimum size of opening in a gas globe?

(729) What is water gas made from? Describe briefly how it is made.

(730) In what ratio does the intensity of light vary with the distance from the source?

(731) (a) The chemical symbol of a certain gas is C_2H_2 . What is the commercial name of this gas? (b) How, and from what substances is it made? (c) Can this gas be burned properly by ordinary lava-tip burners? Give reasons.

(732) If the pressure of the gas, and the length and the diameter of the pipe remain the same, how does a difference in density affect the flow of the gas?

(733) Briefly describe the operation of a dry meter, and mention its advantages over the wet meter.

(734) Suppose that you place a dry governor upon a pipe which supplies a number of common batwing burners, some Welsbach incandescent burners, and some Wenham lamps; to what pressure would you set the governor to obtain the best and most economical results at the burners?

(735) (a) Should gas pipes be run in places exposed to cold weather? Give your reasons. (b) If they must be run in such places, how should they be protected? (c) What must be guarded against when iron gas pipes run very close to electric wires? Where there is danger of contact, what provision should be made?

(736) (a) When will a gas flame smoke, and what is the cause? (b) How may the trouble be remedied?

(737) In piping and connecting up gas stoves, what provision should be made for the products of combustion? Give your reasons.

(738) (a) What are shades commonly employed for? (b) Where are they usually placed about the fixture? (c) What are the requirements of a good shade?

(739) Describe briefly the process of making Archer gas. What is the name derived from?

(740) Distinguish between "refraction" and "reflection."

(741) Briefly describe the use of reflectors and the law which governs reflection.

(742) A certain pipe 100 feet long delivers 185 cubic feet

of gas per hour; how much will it deliver if the length of the pipe is increased full size to 271 feet ?

Ans. 112.32 cubic feet, nearly.

(743) (a) How and where should a meter be set ? (b) How would you approximately determine the internal condition of a dry meter ?

(744) What is the smallest size of a wrought-iron service pipe that you would run for a building ? Give your reasons.

(745) (a) Explain how gas pipes are tested for tightness. (b) How are the leaks discovered ?

(746) (a) In comparing the light produced by burning gases having different proportions of H and C, what is noticeable as regards the intensity ? (b) As an illustration, mention a hydrocarbon gas which burns with intense brilliancy.



ELECTRIC-LIGHT WIRING AND BELL WORK.

(ARTS. 1219-1333.)

EXAMINATION QUESTIONS.

- (747) What is Ohm's Law ?
- (748) How would you define "drop of potential ?"
- (749) What are the three methods of connecting incandescent lamps in circuit ?
- (750) What are the units employed in measurement of current, electromotive force, and resistance ?
- (751) What is an electro-magnet ?
- (752) What is the distinguishing feature of the closed-circuit burglar-alarm system ?
- (753) A group of 30 lamps, 16 c.p., 110 volts, is located 100 feet from the source of current supply. If the drop in potential is $1\frac{1}{4}$ volts, what size wire should be used ?
Ans. No. 6 B. & S.
- (754) What is the difference between series and parallel arrangement of conductors ?
- (755) If the resistance of a wire 3,540 feet long is 2.917 ohms, what is the size of the wire ?
- (756) What is a safety cut-out ?
- (757) What methods are ordinarily used in the production of electric current ?
- (758) What is the area in circular mils of a wire $6\frac{3}{4}$ inches in diameter ?
Ans. 40,640,625 circ. mils.
- (759) A group of lamps is composed of 3 of 50 candle power, 8 of 32 candle power, and 32 of 16 candle power, all

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supplied from a 110-volt circuit. What will be the size of feeders, the distance being 340 feet, and the drop 5 volts?

Ans. No. 4 B. & S.

(760) What method is employed in testing the insulation resistance of house circuits during installation?

(761) Under what circumstances are automatic drops installed on bell circuits?

(762) Explain the action of a pendant burner for electric gas-lighting.

(763) A current of 13.5 amperes is to be transmitted to a bank of 110-volt lamps, distant 320 feet, with 5 per cent. loss in line. (a) What will be the resistance of the two conductors? (b) What is the resistance per foot, assuming each conductor to be 320 feet long? Ans. $\left\{ \begin{array}{l} (a) .43 \text{ ohm.} \\ (b) .00067 \text{ ohm.} \end{array} \right.$

(764) Under what circumstances may single-pole switches be used in a lighting system?

(765) Describe briefly the closet system of house-wiring.

(766) What size of conductor is required for a 110-volt circuit, 540 feet in length from dynamo to lamps, when sixty-five 16 c.p. lamps are used and a drop in potential of 4.5 volts is allowed? Ans. No. 1 B. & S.

(767) What is the special advantage of the three-wire system?

(768) Make a rough sketch showing the different parts of an electric bell, and the path of the current through it.

(769) What apparatus is required to operate electric gas-lighting attachments on the parallel system?

(770) What will be the drop of potential in a 110-volt circuit having 45 lamps of 16 candle power and 4 lamps of 32 candle power, the distance from the dynamo being 165 feet, and the wire No. 6 B. & S.? Ans. 3.59 volts.

(771) What is the principle underlying the use of the loop circuit?

(772) To what classes of installation are cleat work, molding, and concealed work, respectively, best suited?

(773) It is proposed to supply current, by means of a No. 8 wire, to thirty-six 32 c.p. lamps mounted on a chandelier at a distance of 75 feet from the distributing-box, the allowable loss being 3.5 volts. Will this size of wire be correct? Give reasons for your answer.

(774) What consideration should apply in deciding upon the location of the distributing-boxes for inside electric-light wiring?

(775) What alteration is necessary to a vibrating bell in order to change it to one giving a single stroke?

(776) What size wire is generally used in annunciator work (a) for the leading wires? (b) for the battery wire?

(777) What size wire is necessary for a 110-volt loop circuit around the walls of a room 45 feet long by 38 feet broad, thirty-two 16 c.p. lamps being used, and a drop of $1\frac{1}{2}$ per cent. being allowed? Ans. No. 8 B. & S.

(778) In what class of work is the megohm used?

(779) What precautions should be taken when electric light wires are passed through a wall or partition?

(780) A cluster of lights, consisting of ten 16 c.p. lamps and three 32 c.p. lamps, is installed on a 55-volt circuit. A line loss of 2.5 per cent. is allowed, the length of line from closet to lamps being 110 feet. What size wire must be used? Ans. No. 6 B. & S.

(781) Explain the action of a buzzer.

(782) What arrangement may be used to give notice of a short-circuit on a gas-lighting system operated by a battery?

(783) The feeders in a 110-volt lighting circuit are 135 feet in length, and supply current to two hundred and forty 16 c.p. lamps, with a drop of 2 volts. What is the size of conductor in circular mils? Ans. 174,960 circ. mils.

(784) What are the respective advantages of acid and resin as a soldering flux?

(785) What is the object of the neutral wire in the three-wire system?

(786) A feeder 225 feet long, No. 6 wire, supplies current to twenty-five 16 c.p. 55-volt lamps. Disregarding heating effect, what would be the drop of potential on the line?

Ans. 4.624 volts.

(787) How would you proceed in installing a battery of two or three cells, for bell work, if the cells are delivered to you in the original package, as shipped?

(788) In wiring for the multiple-system of electric gas-lighting, what special precautions must be observed?

(789) What means should be employed to take the strain off the connections of a lamp cord inside a rosette?

(790) What will be the drop of potential in a 110-volt circuit, having 46 lamps of 16 candle power, the conductor being No. 4 wire, and its length for the single distance 84 feet?

Ans. 1 volt.

(791) If it is desired to ring bells from a lighting circuit, what arrangements must be made to secure this result?

(792) What is the distinction between a feeder and a main?

(793) A hall dome 120 feet in diameter is fitted with 40 lamps of 50 candle-power each, spaced at equal distances apart, in loop circuit. The E. M. F. of the system is 110 volts, and current is supplied at one side of the circle by feeders 85 feet long. Allowing for a drop of $1\frac{1}{4}$ volts in the feeders, and 2.5 volts in the lamp circuit, what size wire should be used in each case?

Ans. $\left\{ \begin{array}{l} \text{No. 1 wire for the feeder.} \\ \text{No. 0 wire for the lamp circuit.} \end{array} \right.$

(794) Show by means of diagrams the methods of lamp connection in the multiple-arc, the multiple-series, and three-wire systems.

(795) What size wire will be required for an installation on the three-wire system, having sixty-six 110-volt 16 c.p. lamps, the distance between these and the point of supply being 180 feet, and a drop of 2.5 volts being allowed?

Ans. No. 6 wire.

(796) When two or more bells are connected in series, what changes, if any, are necessary in their construction?

(797) When is it advisable to install the flexible two-wire system in a building?

(798) The feeders passing through a building are 80 feet long, and supply current to four hundred and eighty 16 c.p. 110-volt lamps. What size must these conductors be, if the drop of potential is not to exceed 1.25 per cent.?

Ans. 296,000 circ. mils.

(799) Show, by means of a diagram, a method of ringing a bell from either one of two different points.

(800) What will be the drop in voltage on a 55-volt circuit when a loss of 4.6 per cent. is allowed?

Ans. 2.65 volts.

(801) Explain the object of a drip-loop in house-wiring.

(802) An installation on the three-wire system has eighty-four 16 c.p. 110-volt lamps on a circuit 320 feet long, a loss of 3 per cent. being allowed. What size conductor is required?

Ans. No. 7 B. & S.

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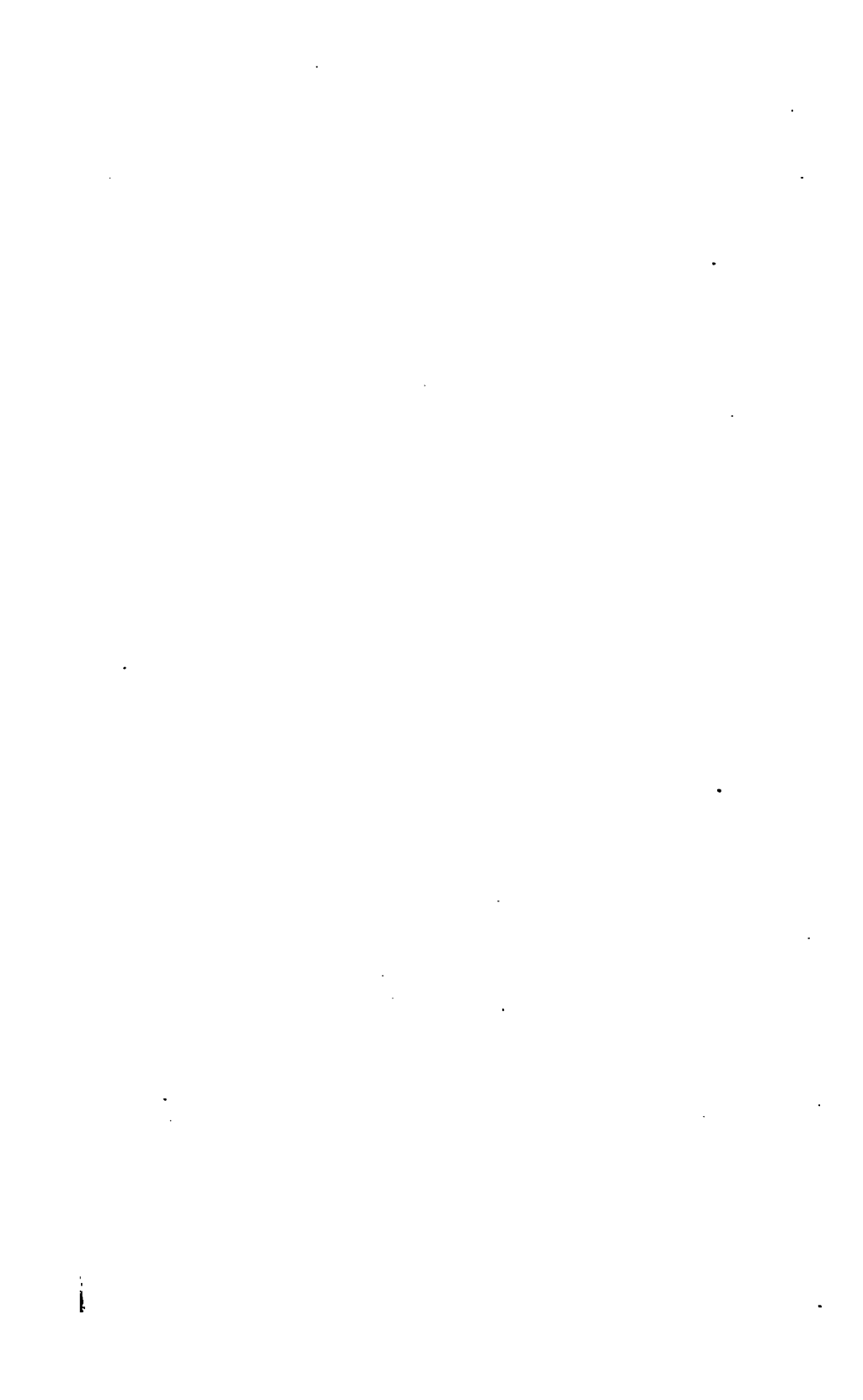
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